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ITERATIONS ON A TRANSMEDIA GAME DESIGN EXPERIENCE FOR YOUTH'S AUTONOMOUS, COLLABORATIVE LEARNING

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Transmedia design, which involves extending a narrative from one medium to another, offers a context for potentially rich, interdisciplinary learning. We explored these opportunities by creating a week-long workshop to guide 7th-grade student teams in designing games based on comic books about viruses. This design case describes the framework and rationale behind our design choices. It illustrates our experiences by drawing on field note observations and audio recordings, student-generated design artifacts, student and facilitator interviews, and planning documentation from across two iterations of the workshop. We reflect on our experiences in attempting to balance (1) the dual focus of the workshop on science learning and game design through our choices of comic and game genres; and (2) the ability for students to be both autonomous and to receive necessary guidance through our enforcement of design constraints and interdependent team roles. We also reflect on the contextual factors that mediated our work, including students' existing interests and peer relations, their teachers' involvement, and our own team's shifting expertise as membership changed from one iteration to the next. Among other things, our experiences highlight the importance of designing to allow for change, particularly as learning through collaborative transmedia game design can occur in unanticipated ways. Finally, we reflect on plans for future iterations of this workshop.

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TRANSMEDIA GAME DESIGN FOR LEARNING

Transmedia game design involves designing a game that extends or elaborates a narrative sourced from a different medium (e.g., a film or book). Examples of transmedia abound in popular culture. The Star Wars, Harry Potter, and Spiderman franchises, for instance, are each examples of narratives told, retold, and extended in the forms of movies, comic books, and games.

We were interested in the potential for transmedia game design to promote youth's science learning. We thus created a workshop in which learners explored ideas in science through their creation of games based on comic books. We call this activity Transmedia Game Design for Learning (TMGDL).

As a collaborative storytelling and design practice (also see Dena, 2010; Jenkins, 2009; Warren, Wakefield & Mills, 2013), TMGDL merges various activities shown to benefit disciplinary learning and engagement.

For example, game design, as a constructionist activity, can develop youth's disciplinary interest, agency, identity, and conceptual understanding (Baytak & Land, 2010; Bonsignore et al. 2016; Harel & Papert, 1991; Kafai, 1995; Kafai et al., 2012; Kafai & Burke, 2015; Kafai, Fields & Searle, 2012; Pepper & Glosson, 2012; Salen, 2007). There are also advantages in learning through narrative (Bruner, 2003; Cohn, 2000; Landau, 1997), comic books (Jee & Angorro, 2012; Matuk, Diamond & Uttal, 2009; Spiegel et al., 2013), playing games (Barab et al., 2012; Ermi & Mayra, 2005; Fullerton, 2008; Liao et al., 2011; Miller et al., 2011), designing (Benenson, 2002; Fortus et al., 2004; Games, 2010, 2011; Guzey et al., 2019; Harel & Papert, 1990, 1991; Kafai, 1995, 2003; Kafai et al., 2012; Kafai, Fields & Searle, 2012; Pinkard et al., 2017; Kolodner et al., 1998; New London Group, 1996; Peppler & Glosson, 2012; Salen, 2017), and collaborating with peers (Johnson & Johnson, 1985, 1999; Jonassen, 1991, 1994). Thus, TMGDL offers opportunities for youth to develop skills for tackling real-world problems, to realize the relevance of domain knowledge, and to connect these to their personal interests (Ito et al., 2013). At the same time, supporting TMGDL presents unique design challenges, particularly due to the interdisciplinary nature of transmedia, and to its location at the intersection of youths' formal and informal experiences.

This design case (Boling, 2010; Howard et al., 2012; Smith, 2010) documents our iterations on a week-long workshop, in which we guided 7th-grade students through the collaborative transmedia design of non-digital science games. We describe our complementary goals as researchers, designers, and educators; and explain the embodiment of our guiding principles in the workshop's design. We then discuss how we adapted the workshop in response to the design tensions we experienced. Finally, we reflect on insights gained from our process, and on future directions for this workshop.

BACKGROUND & RATIONALE

Workshop Origins

Our workshop originated with the invitation of one of Author 1's long-time collaborators to use their comic book series, World of Viruses (WoV, Diamond, 2012), as a resource in her research. WoV was part of a research and development project to promote youths' awareness of virology (Diamond et al., 2012; 2015). The series consists of several professionally-produced comic stories targeted at middle and high school youth that each revolves around the science, cultural history, and societal impact of a type of particular virus. Each comic offers several pages of a self-contained narrative that incorporated, to varying extents, elements of fantasy, science fiction, and science fact. This invitation to explore the learning opportunities in comic books was appealing, particularly given prior research on the power of comics to motivate learners (Diamond et al., 2015; Dorrell et al., 1995; Ogier & Ghosh, 2017; Tatalovic, 2009) and to increase disciplinary interest and identity (Nagata, 1999; Spiegel et al., 2013); and to the potential for science fiction as a context for practicing aspects of science thinking (e.g., Smith & Shen, 2017).

Camillia Matuk, a New York University faculty member with a research focus on learning environment design, had the broad goal of creating a new context for supporting and researching youth's STEM learning. She sent an open invitation to graduate students in her program, and to students already working with her on other projects, to join her efforts. Several students responded to this invitation and joined initial planning meetings. Whereas a few project members dropped out early on to focus on their coursework, those who remained to see the project through did so because they wished to gain skills in design-based research, learning environment design, and youth leadership; to explore comic books as learning materials, and to apply foundational knowledge learned in their courses to a real-world learning context.

In several early project meetings, we discussed our interests in the project and our individual goals and expertise. After brainstorming various possibilities for using the comic stories in our work, we ultimately settled on the idea to host a youth transmedia game design workshop: an effort that would combine our collective expertise and interests in science education, narrative learning, game design, game-based learning, design thinking, and design-based research.

The format of this workshop emerged opportunistically. Author 4, who was at the time an intern at a local school, identified a teacher partner and arranged for our group to visit his weekly 7th-grade lunch-hour club in order to pilot activity designs with the students. Through these activities, we explored ways to introduce and discuss a given comic book, playtested games we had ourselves designed based on the comics, and led discussions with students on their interests in comic books, games, and transmedia franchises.

After several such visits to the school, the head science teacher invited us to host a week-long workshop for grade 7 students. This workshop would occur within an established school-led program, which dedicates one week during each of the Fall and Spring semesters (December and June, respectively) to be culminating experiences for students. Workshops during this week are intended to provide realistic contexts in which students can apply ideas learned during their regular classes. Our workshop would be one of several other choices offered by the school's teachers and industry partners, which cover such domains as public art, fashion, entrepreneurship, and the culinary arts (e.g., design a restaurant; make a documentary about your city; create a public art piece).

To determine participation in these workshops, the school distributed brief descriptions of them along with the names of their lead teachers approximately 2-3 weeks before they were to begin. Students ranked these workshops in terms of preference. The school then assigned students to the workshops based on their choice rankings and based on a cap of 11-15 students per workshop. One week before the workshops were to begin, the school notified students and workshop hosts of the assignments. Most participants in our workshop had chosen it as their 1st or 2nd choice.

Comic books, viruses, and games (Oh my!)

In this Boss Level, you will partner with game designers from New York University to create a game that teaches players about viruses.

Viruses are implicated in nearly every aspect of human experience. They shape the biology of humans and ecosystems; have caused the collapse of great civilizations; drive scientific discoveries; and define relationships among living things. Deadly viruses are now mostly eradicated, but public misunderstandings of viruses have serious implications. In 2014, for example, fear of vaccines caused one of the worst preventable measles outbreaks in decades.

One series of comic books (worldofviruses.unl.edu/comics-apps) aims to increase public interest and awareness of viruses. Our challenge is to design a game based on the latest addition, Measles, by Marvel comic creator Bob Hall. Together with game designers from New York University, you will read the comic, playtest existing health games, visit NYU's (MAGNET) Media and Games Network for inspiration, and ultimately use the story and the science of measles to create original health education games. Promising designs will later be professionally developed and published for use by teachers and youth within and beyond Quest to Learn.

FIGURE 1. The workshop description distributed to students, which was one among several other choices of activities that they ranked in terms of preference.

In this design case, we describe the first two iterations of our workshop, held in June and December 2017. In June 2017, we framed it as an educational game design challenge that highlighted the topic of viruses, the use of a comic book, and the opportunity to work at our university during the week. The same workshop description was used to recruit students for both the June and December iterations (Figure 1), although the content and goals of our second iteration changed, as we will discuss next.

Design Goals

Our overarching goal in organizing this workshop was to explore the affordances of a collaborative transmedia game design context for supporting students' dispositional development toward STEM. Specifically, we were interested in having students to experience the collaborative design process within an authentic task. From this, we wished to explore students' developing knowledge of, attitudes toward, and identities related to game design and science, the role of guidance and facilitation; how learning occurs through the collaborative transmedia game design process; and the impact that narrative has on scientific thinking and practices. As designers, we wished to create an environment that would increase students' interest and participation in science, as well as their awareness of game design as a profession. We also wished to create and refine principles and activity structures that might be reusable in other contexts and with other youth participants, and that would inform others' similar design efforts. These efforts have led to conference publications and presentations (e.g., Hovey, Matuk & Hurwich, 2018; Levy-Cohen & Matuk, 2017; Matuk, Hurwich & Amato, 2019; Matuk, Levy-Cohen & Pawar, 2016).

We hoped that students would come away from the workshop with (1) techniques for translating a narrative between comic and game formats; (2) an understanding of the structure of games of a particular genre (educational games in June and role-playing games in December); and (3) how to apply the design process to a complex, collaborative task.

OVERVIEW OF THE WORKSHOP DESIGN

Guiding Frameworks

Features of our workshop were informed by principles for encouraging disciplinary engagement (Engle & Conant, 2002): (1) Encourage youth to tackle complex problems (e.g., Hiebert et al., 1996; Warren & Rosebery, 1996); (2) Create conditions in which youth have agency to address those problems (e.g., Lampert, 1990a; Scardamalia, Bereiter, & Lamon, 1994; Wertsch & Toma, 1995); (3) Establish a system in which youth are accountable to each other and to norms of a discipline (e.g., Cobb et al., 1997; Lampert, 1990b), and (4) Provide necessary scaffolding and resources for youth to accomplish their goals (e.g., Barron et al., 1998).

These principles were embodied in several features of our workshop, and in ways that address challenges specific to our TMGDL context (Table 1) (1) help youth to identify promising themes from a narrative source and express these as game mechanics; (2) explicitly model and guide productive collaborative design practices through brainstorming, playtesting, feedback, and iteration; (3) balance individual and collaborative goals by supporting distinct but complementary team roles; (4) expose students to expert perspectives on games, science, and comics and (5) attend to the affective and interest-based components of learning experiences through icebreakers and play-filled downtime.

This approach largely drew inspiration from related research (e.g., Bonsignore, et al., 2016; Smith & Shen, 2017); from our individual prior experiences working with youth, designing games, teaching the design process, and creating science learning environments; and from our experiences trialing workshop activities with middle school students over the previous several weeks.

DESIGN PRINCIPLE AND RATIONALE	DESIGN EMBODIMENT
Encourage youth to tackle complex problems. This creates opportunities to practice skills and to apply knowledge in authentic contexts.	Students were tasked with designing a game based on a comic narrative with learning content. This task shares similarities with other kinds of complex problems: it requires setting goals, making and evaluating decisions based on outcomes, iterative refinement, and the application and integration of multiple perspectives and sources of knowledge.
Create conditions in which youth have the agency to address those problems. The ability to exercise agency is related to identity formation, which itself is related to longer-term achievement.	We defined and gave students the choice of, and flexibility to move among unique and interdependent team roles. Through these, students could choose to contribute in the ways that they felt aligned with their strengths and interests. We defined a design task that constrained students in productive ways (e.g., to extend the comic's narrative and to address science in some way) with the freedom to be creative.
Establish a system in which youth are accountable to each other. Being able to collaborate in groups is an important skill for lifelong success.	We attended to the affective and interest-based components of learning experiences (e.g., easing activity transitions, fostering trust and camaraderie, leaving space to pursue individual curiosities) through icebreakers and playful downtime (e.g., time after lunch to play video games). We defined interdependent roles such that each set of responsibilities required the collaborative input of the others in order to achieve the team's overall goal. Daily deliverables and occasional progress reports kept students on track, as well as accountable to each of their teammates and to the whole group.
Structure activities that encourage accountability toward the norms of a domain or discipline. Students interested in pursuing these fields should become familiar with the norms and practices, while all students can stand to gain from learning to apply disciplinary ways of thinking to new problems.	We organized the week's activities and deliverables to generally follow the professional design process. Specific to TMGDL, we incorporated activities to help students to identify promising themes from a narrative source and express these as game mechanics. We incorporated expert perspectives on games, science, and comics by having facilitators with that expertise lead sessions, or by inviting guest experts to facilitate certain sessions.
Provide necessary scaffolding and resources for youth to accomplish their goals. Having sufficient resources enables work toward one's goals, rather than an effort to accommodate one's deficiencies.	Resources were available to support students' work, including game examples, art and prototyping materials, and a computer lab with internet access. We led activities that explicitly addressed productive collaborative practices in brainstorming, playtesting, feedback, and iteration; helped students to understand the relevant science content from the comic and led students to play and discussing examples of existing games in order to guide them in thinking about their own game designs. We created design templates (e.g., character sheets, playtest feedback forms) that gave students a starting point for developing their ideas.

TABLE 1. Guiding design principles, their rationales, and general embodiments across both versions of the workshop..

Context and participants

Participants of both workshops were students and teachers from a diverse public middle school in a large urban city in the mid-Atlantic United States. The school's general approach was based on principles of game-based learning. Thus, students were familiar with various game genres and with the design process, as these were both of personal interest to many students, and featured heavily in various curricular and extracurricular activities.

Upon our request, the head science teacher (who had become Vice-Principal by our workshop's second iteration) actively recruited a diverse group of students to participate in our June workshop. They included eleven grade 7 students (4 females, 7 males; 2 Black, 6 Caucasian, 3 Asian). Two teachers from the school (1 male, 1 female) were also present and played supportive roles in addition to chaperoning students during lunch breaks. Up to 7 facilitators were present on each day: Two main facilitators who were present throughout the week, and 2-3 others who joined to lead certain activities based on their expertise.

In December, we did not actively seek to balance the genders represented. The students who participated were 13 male students in 7th grade (2 Black/African American, 1 Caucasian, 4 Asian, 1 Caucasian-Hispanic, 1 Caucasian-Native American, 4 not reported). One female teacher from the school was present throughout the workshop, and in addition to chaperoning the students, also acted as a participant alongside them. Between 4-6 facilitators were present throughout the week, and in contrast to the June workshop, the team was largely consistent throughout the week.

OUR DESIGN PROCESS

Deciding on, and mapping out activities

Led by Author 1, we coordinated our efforts through weekly meetings and comments in shared Google documents. Around three months before the start of each workshop, our project team met approximately once per week to define our research goals and conceptual framework, both of which would inform the ways we would structure the activities and ways for students to participate. After determining that we wanted students to have created a playable game prototype by Day 5, we mapped out the necessary milestones across the four previous days, defined deliverables for each milestone, and planned activities to support students in producing those deliverables. We then delegated amongst ourselves the responsibilities for planning the activities (e.g., the process for forming student teams; the discussion we would facilitate about viruses) based on project members' interests and prior experiences. Part of this work involved creating informational handouts and worksheets, presentation slides, and an internal agenda for facilitators that included notes on specific responsibilities, key points to address, ways to prompt student discussion, and guidelines for orchestrating the logistics of the activities and their transitions. Project members presented ideas-in-progress at subsequent meetings, during which we collectively discussed and refined them, and planned next steps for developing them.

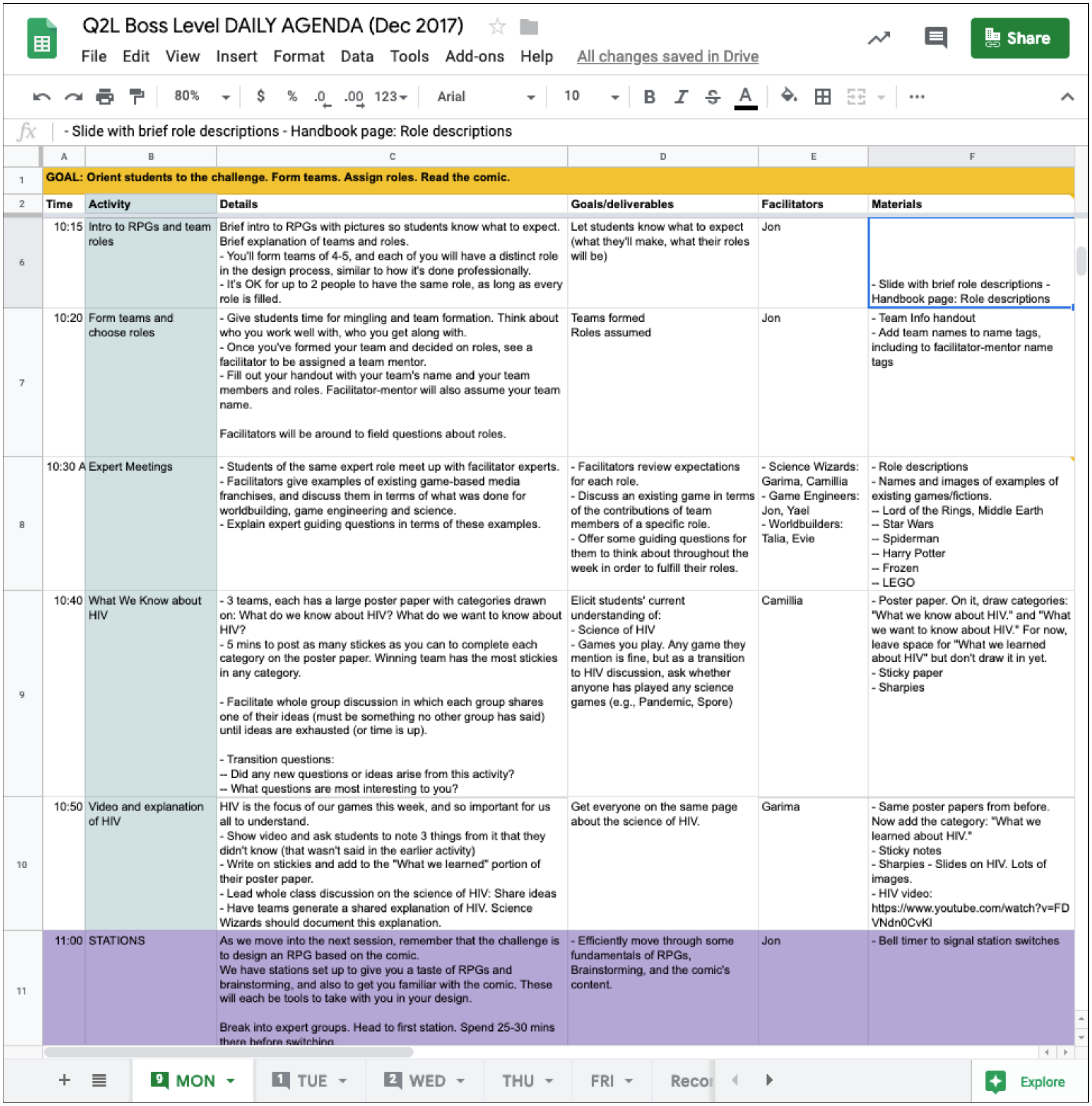
Often, these project team discussions would surface alternative approaches to our goals. For example, should students form their own teams, should we guide team formation, or should we ask teachers to use their own criteria to create teams beforehand? To decide among these alternatives, we discussed their pros and cons, consider how each aligned with our broader goals for the workshop and evaluated the practicality of their implementation within our given constraints (e.g., would the format of the workshop and our own collective skill set allow us to successfully enact a given approach?). When multiple approaches seemed equally viable, we agreed to first pursue the one that seemed most interesting from a research standpoint and to try other options in future iterations. For example, we chose to predefine team roles from which students would choose as opposed to leaving these roles undefined. We did this because understanding student identity in a design context was one of our research interests, and this approach would allow us to better document how students would ultimately negotiate their identities with respect to their roles as we envisioned them.

Consulting with teachers

At our participating school, industry partners have been responsible for designing and facilitating the workshops that they host for students. Still, each workshop has an appointed supervising teacher, a role that teachers volunteer to perform based on their interests and availability. In this role, teachers serve as points of contact between hosts and the students and parents, and as chaperones to students during the week. They tend not to be active design partners alongside the hosts, nor facilitators of the workshop.

Because we were new to hosting such workshops, and because we recognized that teachers' knowledge of their students would be informative to our plans, we invited our supervising teachers to engage in our design process. Mindful of teachers' limited time, we met face-to-face with them only at the early, middle, and late stages of our progress.

During these meetings, we discussed our plans and goals and sought their insights on specific questions (e.g., What prior knowledge should we expect of students? What strategies for structuring student teams were likely to be most successful?). We used Google Drive to share our planning documents with the teachers. Initially, our project team used these documents to maintain running notes on ideas for activities as they arose in our discussions. Later, as



	A	B	C	D	E	F
1	GOAL: Orient students to the challenge. Form teams. Assign roles. Read the comic.					
2	Time	Activity	Details	Goals/deliverables	Facilitators	Materials
6	10:15	Intro to RPGs and team roles	Brief intro to RPGs with pictures so students know what to expect. Brief explanation of teams and roles. - You'll form teams of 4-5, and each of you will have a distinct role in the design process, similar to how it's done professionally. - It's OK for up to 2 people to have the same role, as long as every role is filled.	Let students know what to expect (what they'll make, what their roles will be)	Jon	- Slide with brief role descriptions - Handbook page: Role descriptions
7	10:20	Form teams and choose roles	- Give students time for mingling and team formation. Think about who you work well with, who you get along with. - Once you've formed your team and decided on roles, see a facilitator to be assigned a team mentor. - Fill out your handout with your team's name and your team members and roles. Facilitator-mentor will also assume your team name. Facilitators will be around to field questions about roles.	Teams formed Roles assumed	Jon	- Team Info handout - Add team names to name tags, including to facilitator-mentor name tags
8	10:30 A	Expert Meetings	- Students of the same expert role meet up with facilitator experts. - Facilitators give examples of existing game-based media franchises, and discuss them in terms of what was done for worldbuilding, game engineering and science. - Explain expert guiding questions in terms of these examples.	- Facilitators review expectations for each role. - Discuss an existing game in terms of the contributions of team members of a specific role. - Offer some guiding questions for them to think about throughout the week in order to fulfill their roles.	- Science Wizards: Garima, Camillia - Game Engineers: Jon, Yael - Worldbuilders: Talia, Evie	- Role descriptions - Names and images of examples of existing games/fictions. -- Lord of the Rings, Middle Earth -- Star Wars -- Spiderman -- Harry Potter -- Frozen -- LEGO
9	10:40	What We Know about HIV	- 3 teams, each has a large poster paper with categories drawn on: What do we know about HIV? What do we want to know about HIV? - 5 mins to post as many stickes as you can to complete each category on the poster paper. Winning team has the most stickies in any category. - Facilitate whole group discussion in which each group shares one of their ideas (must be something no other group has said) until ideas are exhausted (or time is up). - Transition questions: -- Did any new questions or ideas arise from this activity? -- What questions are most interesting to you?	Elicit students' current understanding of: - Science of HIV - Games you play. Any game they mention is fine, but as a transition to HIV discussion, ask whether anyone has played any science games (e.g., Pandemic, Spore)	Camillia	- Poster paper. On it, draw categories: "What we know about HIV." and "What we want to know about HIV." For now, leave space for "What we learned about HIV" but don't draw it in yet. - Sticky paper - Sharpies
10	10:50	Video and explanation of HIV	HIV is the focus of our games this week, and so important for us all to understand. - Show video and ask students to note 3 things from it that they didn't know (that wasn't said in the earlier activity) - Write on stickies and add to the "What we learned" portion of their poster paper. - Lead whole class discussion on the science of HIV: Share ideas - Have teams generate a shared explanation of HIV. Science Wizards should document this explanation.	Get everyone on the same page about the science of HIV.	Garima	- Same poster papers from before. Now add the category: "What we learned about HIV." - Sticky notes - Sharpies - Slides on HIV. Lots of images. - HIV video: https://www.youtube.com/watch?v=FDVNdn0CvKI
11	11:00	STATIONS	As we move into the next session, remember that the challenge is to design an RPG based on the comic. We have stations set up to give you a taste of RPGs and brainstorming, and also to get you familiar with the comic. These will each be tools to take with you in your design. Break into expert groups. Head to first station. Spend 25-30 mins there before switching	- Efficiently move through some fundamentals of RPGs, Brainstorming, and the comic's content.	Jon	- Bell timer to signal station switches

FIGURE 2. An internal agenda used to guide our enactment of the December 2017 workshop. The spreadsheet details daily activities, facilitator roles, and corresponding materials needed to carry out the activities.

our decisions solidified, we developed daily internal agendas in spreadsheets, which used columns to detail the activities, their start times, intended goals, main points/processes to be covered, lead facilitators, setup instructions, and links to required materials (Figure 2). Although we invited the teachers to contribute their ideas and questions to these documents, they instead chose to only use them to stay informed of our plans.

Internal playtesting

Internal playtesting was critical to our project team's design process and helped to ensure that our workshop's activities were reasonably complex and achievable by students. In preparation for the June workshop, for example, our project team reviewed existing educational games related to health and virology and designed two of our own virus-related games. This allowed us to experience any peculiarities of the design process for ourselves and to better understand where students might require our support. We ultimately led students in playing those games during the workshops that we had designed in order to generate discussion about design strengths and weaknesses and to inspire students' own games.

In December, Author 3 led our project team in playing a simplified role-playing game (RPG) that he had designed for one of his class projects (Figure 3). As most of our project team was new to the RPG genre, this experience, along with Author 3's commentary on his design decisions, allowed us to understand the complexities involved in creating such a game. Together, we identified which areas would be challenging for students, and how we might modify the process such that during the workshop, those students could achieve a concrete deliverable in the given time, and find opportunities to express their own ideas.

This RPG that Author 3 designed was also the example that we gave to students to inspire their own RPGs. We chose this RPG because Author 3 would be able to explain his decisions and experience as the RPG's designer, which we believed would offer students with helpful insight into the RPG design process that they would be undertaking themselves throughout the workshop. We also chose this RPG because, as its designer, Author 3 was prepared to modify it to fit within emergent time constraints of the workshop, while still highlighting important aspects for the students to note.

Reflecting on outcomes and prioritizing next steps

During each workshop, enactment, 1-2 of our project team members, when they were not facilitating students' activities, documented observations in the form of field notes within a shared Google document. The rest of the project team amended this document with their own observations throughout the week. Some project members additionally shared individual reflections written following the workshop's end.

Several weeks after the first iteration (when project members returned from the academic break), we held a meeting to debrief on our experiences with the first workshop. One of our goals in doing so was to identify productive directions for analyzing the data that we had collected and for writing up our findings for publication. A second goal was to reflect on our challenges and successes in order to inform our approach to the next iteration.

Author 1 opened this reflection session by asking project team members to share their opinions on "what worked and what didn't?" One person would offer a comment or observation, which others would corroborate, augment, or counter with an alternative interpretation or experience. Author 1 documented this discussion in a shared Google document, and then translated the points raised into guidelines for our next steps.

The areas on which we decided to focus were based on Author 1's desire to preserve certain aspects of our workshop's first iteration. The first such aspect was a focus on students designing games. Game design was in line with the skill set of our project team members, and a known interest of the youth for whom we were preparing the workshops. The second aspect that we wished to maintain was students designing based on comic books. This decision stemmed both from Author 1's long-time research interest in the learning affordances of graphic narratives, and in her desire to more deeply explore the WoV comic series, given her collaborators' active encouragement and support.

The third aspect that we decided to maintain from the first to the second workshop iteration was student team collaboration. Collaborative learning is a focus of Author 1's research and a key aspect of our guiding framework for designing to support disciplinary engagement. It is also a skill that our participating school valued and promoted in their other workshop offerings. Knowing that we wanted to continue to support student collaboration in our next workshop, we decided to focus on addressing the challenges that we experienced in June in coordinating students to work together. We were especially interested in refining approaches to support both students' individual agency and their team interdependence, a balance that we found to be uniquely compelling in the TMGDL context because it combined design practices with interdisciplinarity. Choosing to maintain and refine these aspects from our first workshop would allow us to begin building a consistent research program, in which each iteration would contribute to our broader goal of deepening our understanding of the opportunities in TMGDL.

At the same time, we were curious to explore new directions to best understand the learning potential of this space. Within the aspects that we agreed to keep consistent, we thus reconsidered our choice of comic that would serve as the foundational text and the game genre that we would ask students to design. The latter decision was largely influenced by Author 3, who had joined us as we were beginning preparations for the next iteration, and introduced new expertise to our project team. We further discuss our rationale for our changes next.

Preparing to be flexible

It was important for us to be both prepared to guide students through challenges we anticipated, as well as flexible to adapt to opportunities and constraints that we might encounter. Thus, at the end of each day, we held a debriefing session with the students to ask which activities they liked and disliked. We also debriefed as a team after the students' departure in order to share perspectives on what we believed was and was not working and to plan the next day's activities, such as to address students' current needs and help them meet the milestones. For example, when students

Adventure Quest

Overview –
Adventure Quest is a cooperative adventuring game for 3-6 players where players take on the role of fantasy heroes who explore dungeons for glory and treasure. In Adventure Quest, you will role-play, explore, and fight alongside your adventuring party to overcome obstacles and encounters to reach the end of the dungeon.

Rules of Play –
- Each player takes 1-2 characters and act as those characters during the game.
- One player will act as the Adversary, who controls all of the aspects of the game other than the player characters.
- For any action you want to take in the game, you may roll the 20-sided die (d20), which is called making a check. Higher rolls are more likely to succeed, and lower rolls are less likely. The Adversary will determine whether a check has passed, and describe what happens as a result. Different checks have different Difficulty Challenges (DC), which must be met in order for a check to be successful. If a player rolls a 20 on a check, they succeed with a critical success. If they roll a 1, they fail with a critical failure.

DC	Difficulty to Complete a Challenge
5	Easy
10	Doable
15	Difficult
20	Very Difficulty

The Turn –
Each player's turn consists of two parts: Movement, and taking an Action. Players may take either part of the turn first, and they may split their movement up to before and after they take their action. Players may also spend their Action to take a second Move Action.
- **Types of Actions –**
    - **Movement** – Your character may move up to the number of squares designated on their character card. Other actions, such as hiding or mounting a horse require a move action.
    - **Attack** – A character can attack with a weapon they have equipped.
    - **Encounter Actions -** Encounter Actions require an Action, and can only be used once per encounter. Once the players are away from the encounter for at least 1 minute, they will regain use of their encounter abilities.
    - **Adventure Actions -** Adventure Actions require an Action, and can only be used once per adventure, or per play session of Adventure Quest.
    - **Other Actions -** If during combat players want to take some kind of significant action (closing and locking a door, dropping a chandelier, making a plea bargain with an enemy, etc.), this will also take up their action. Minor actions, such as saying a few words or drawing a weapon do not require a turn action.

Character Attributes –
- **Stats** – The 4 core stats of your character – Strength, Agility, Intelligence, and Charisma – represent what your character is good at. Whenever you want to take an action that would be associated with one of these stats, add your character's bonus to the d20 roll. Your character's stats are already accounted for in their attacks.
- **Health** – This represents your character's remaining life force. When your Health reaches 0, you will become downed. See Death and Dying for more info.
- **Armor** - A character's Armor reduces damage that the character takes from an attack by an amount equal to the character's armor. Damage reduced to 0 has no effect. Characters who take negative damage take no damage instead.
- **Movement** – Movement is the number of squares your character can move across the board. Each board square represents 5' of space.
- **Attacks** – Each character has a set of attacks with weapons they begin the adventure with. If they acquire a new weapon, the weapon card will indicate how much damage it does and what stat to add to it for damage.
- **Special Abilities** – Each character has a number of special abilities associated with them. Players may choose to take these actions, as described on the character cards. Be sure to mark down once players use abilities once per adventure, or once per encounter.

Combat –
When the players choose to engage with enemies, first determine initiative, and then allow the players to take their turns as described above. When all hostile characters are defeated, or the players stop fighting, you may leave initiative order.
- **Initiative** - During combat, follow this order to determine initiative:
    1. Characters with Quick Reflexes
    2. Bosses
    3. Player Characters (They determine their own order)
    4. Normal Enemies

  If players cannot determine their own order, each player rolls 1d20, and players will go in descending order.
- **Attacking** - When one character attacks another, roll the die for the weapon being attacked with. The defending character subtracts their Armor from the total, and then takes the remaining amount as damage to their Health.
- **Death and Dying** - If your character reaches 0 hit points, they are downed, and cannot act. If an ally comes over and spends an **action** aiding them, the character will recover 1HP. If a character is not aided in 3 rounds, they will die.
- **Working Together –** Adventure Quest is a cooperative game, and players are not allowed to attack each other.

FIGURE 3. Description of a simplified RPG called Adventure Quest, designed by Author 3.

in December told us that they found it helpful to play and learn about the design of Author 3's RPG, we incorporated an expert workshop in which Author 3 took teams aside to play through examples of RPGs and to discuss improvements for their own designs.

Design Agreements and Constraints

We agreed on certain design constraints upfront, based on the existing constraints imposed by our partners, the context, and on our own team's resources and expertise. These agreements were:

1. *Keep students' activities within five consecutive 5-hour days:* All activities would have to take place within 4 days, with the final day being reserved for a school exhibition of students' projects.
2. *Assign no prep-work or homework:* All the work would have to take place within the designated week, as per the school's tradition with this program.
3. *Focus on non-digital games:* This decision was made to address the technological hurdles to designing a digital game. Indeed, non-digital games lower equipment costs; broaden accessibility to youth who may range in their technical interests and proficiencies; introduce physical representations useful for coordinating collaboration; and provide opportunities to promote social and emotional learning in ways that digital games cannot (Fang et al., 2016).

WORKSHOP OVERVIEW

1st Iteration: June 2017

In our first iteration, which took place during the second last week of June 2017, we tasked student teams with designing original, educational games to accompany *Carnival of Contagion* (Hall, West & Diamond, 2017), a WoV comic about a group of unvaccinated youth who become infected with the measles virus, and share a strange dream as they experience its symptoms (Figure 4).

Activities during the first four days took place in a classroom at our university. During that time, we led student teams in reading the comic, and then guided them through a process of brainstorming and prototyping ideas, and playtesting and refining their final game prototypes (Figure 5). On the fifth and final day, students held a game jam at their own school, in which they explained what they had done during the week, and then as groups, led their other peers in playing the games they designed (Table 2). The idea for a game jam came from the teacher who chaperoned the students during the week. A game jam was a format that allowed other students to experience the games that our workshop participants had created, and that fit within the time constraints of that particular school day, during which students from other workshops were also exhibiting the projects that they had completed that week.

One of the major goals of the workshop was to present a clear and discrete task with many routes to success. We hoped to offer each group of students the option to come up with their own solutions. However, they were ultimately responsible for the success of each step, and if their strategy did not succeed, we would intervene as facilitators to help redirect them to their goal.

To help inspire students' ideas, we led them in playing and discussing games that we had modified to convey particular science concepts related to virology. In one activity, we modified an existing online game called Sneeze! (Channel 4, 2008) In it, each student was dealt a card indicated a secret identity: a black suit indicated that they were healthy but susceptible to measles; a red suit indicated they were vaccinated and immune to measles; a joker card indicated that they were the measles virus. Healthy individuals aimed to remain healthy, while the measles virus aimed to infect as many people as possible. Students played the game by walking around a room, with the measles virus, incognito among them. When the measles virus mimicked sneezing, susceptible players at arm's length would become infected and would withdraw.

Another game we played with students was our modification of the party game, Werewolf (Davidoff , 1986; Plotkin, 1997), which we named Weasels (a combination of "Werewolf" and "measles"). In it, students played vaccinated or unvaccinated villagers. Each "night," the villagers closed their eyes, and a player with the secret measles identity selected a villager to infect. One by one, susceptible villagers and their neighbors caught measles and withdrew from the game. The remaining villagers voted on whom to quarantine based on whom they believed was unvaccinated. The game continued until either measles or the villagers outnumbered the other.In playing and reflecting upon each of these games, students came to know how easily measles spreads via unvaccinated hosts. By discussing modifications to these games and predicting their outcomes (e.g., varying the ratio of vaccinated to unvaccinated players), students were able to apply a degree of systems thinking and an awareness of the social responsibility of vaccination.

2nd Iteration: December 2017

In this second iteration, we had students read *Phantom Planet* (Powell et al., 2012), a WoV comic about the human immunodeficiency virus (HIV). Set in a future in which HIV has overtaken Earth, two scientists from a planet colonized years ago visit Earth to retrieve samples of HIV-resistant cells in order to develop a cure to save humanity (Figure 6). We asked students to use the narrative and science told in this comic as a basis for designing their own tabletop role-playing games (RPGs) (see next for the rationale behind this decision). Across the four days, we led rotating sessions in which we introduced students to the comic's story and

FIGURE 4. Two pages from the comic, *Carnival of Contagion*. Used with permission of Judy Diamond. Hall, B., West, J. & Diamond, J. (2017). *Carnival of Contagion*. Lincoln, NE: University of Nebraska Press.

had them play a simplified RPG designed by Author 3 (Figure 3). We then guided teams in brainstorming and elaborating their game's narrative and the world, incorporating the science content, prototyping, playtesting and refining their designs (Table 3). As in the June iteration, students' exhibited their final games on the fifth day of the workshop, which took place at the students' school. Given the complexity and length of RPGs and the time it takes for new players to become used to playing them, the students played their own games before an audience of their school peers, who observed and asked them questions about their design choices.

BALANCING FOCUS ON SCIENCE CONTENT VS. GAMES

Through our workshop, we aimed for science learning to be integral to game making. In our view, having students design a game naturally involves scientific skills and practices such as prediction, experimentation, and systems thinking. We hoped that these practices would be further brought out by an activity grounded in the scientific narrative of the comic. At the same time, we were aware that students, used to the disciplinary divisions presented to them by formal schooling, might not easily perceive the parallels between game design and science as we did. We moreover, anticipated that students might not be intrinsically motivated to incorporate science into their game designs. Finally, we experienced our own challenges in creating support for the informal activity of game making that was simultaneously intended to align with the formal expectations of traditional science learning.

By the December iteration, we had shifted in our principles for supporting students' science learning through game making. In our hope to observe students' unanticipated science learning, we realized that we had to design for the possibility of science learning, without the explicit expectation of science learning. Thus, whereas our first iteration focused on helping students to learn concrete science concepts by having them explicitly teach those concepts through their game designs, as described next, our second iteration focused on engaging students in science practices

FIGURE 5. Two of the students' final board game prototypes from the 1st iteration of the workshop in June. To win at the game pictured at the top, players must be the first to collect the ingredients necessary to make a vaccine and to reach the hospital. Infection spreads when players land on the same square at the same time. To win at the game pictured at the bottom, players, infected by measles, must be the first to reach the hospital. Depending on the squares upon which they land, players pick up cards that specify positive or negative events (Oh No!!! or Treasure), players' death, or a fact about measles.

by embedding these in the process of designing a good game.

While we still administered a pre- and post-assessment in December, this was in the spirit of exploring what content students might learn from the workshop, rather than as a way of evaluating the workshop's effectiveness at teaching that content. We had also incorporated new items to capture students' changing dispositions toward science (e.g., the degree to which they identify with science, they persistence in science-related challenges), which added to June's assessment items that merely captured students' changing interests in science.

Two decisions were key for us in balancing the emphasis of our workshop between science and games. These decisions moreover reflect our project team's changing views of where to find learning from game design, and how to support it. These decisions were: (1) the choice of comic that would be the starting point for students' designs, and (2) the choice of game genre that students would design. We discuss each of these decisions next.

Which comic book should serve as the foundational narrative?

Our decision over which *World of Viruses* comic book should serve as the foundational text for students' transmedia games were based on two main criteria. First, the comic should offer rich narrative source material upon which students could build their own game worlds, including a setting, cast of characters, and design aesthetic. Another criterion was for the story to introduce science ideas of a degree of complexity that would stimulate students' imaginations about "what if" scenarios. This, we hoped, would engage students in making scientific predictions based on their game's narrative.

1st iteration: Carnival of Contagion

In June, we chose *Carnival of Contagion* (Hall, West & Diamond, 2017) as the foundational text. As described earlier, this comic followed a group of unvaccinated youth who become infected with measles. As they begin to experience the symptoms of measles, they share a disturbing dream in which a carnival barker and his pet dragon, which are personifications of the measles virus, guide them through an abandoned carnival ground. This comic was primarily chosen for our first iteration as it was, at the time, yet to be published. Reading the draft provided to us by its comic creator, Marvel Comics veteran Bob Hall, added to the authenticity of students' roles as designers.

We also believed that the abandoned carnival setting would offer an austere aesthetic that would appeal to the students and inspire their own games. Most importantly, *Carnival of Contagion* addressed the importance of vaccination, which led naturally to discussions of, and group activities for illustrating the concept of herd immunity. This topic held potential for students to realize the personal and societal relevance of virology, and to offer a rich interdisciplinary starting point to inspire their own games' learning goals.

However, what we anticipated was not ultimately what transpired. Instead, the science in students' own games mostly revolved around naming the symptoms of measles. In one student team's game, for instance, players progressed through increasingly severe symptoms of measles as they rolled the die and landed on particular squares along a path. While this design cleverly implicates the element of chance involved in different people's experiences with measles, it does not attempt to incorporate, for example, the biological processes that underlie those symptoms, and that would have required a deeper integration of the science ideas introduced in the comic, and those that the students might have incorporated through extra research. In short, their game mostly stuck to the script of the comic in that it did not venture beyond the science content contained in it. Interestingly, this game as well as the other two contained few to none of the narrative elements from *Carnival of Contagion*, in spite of our encouragement to draw from the comic.

FIGURE 6. A page from the *World of Viruses* comic, *Phantom Planet*. Used with permission of Judy Diamond. Powell, M., Angeletti, P., Angeletti, A., & Floyd, T. (2012). *Phantom Planet*. In Diamond, J., Floyd, T., Powell, M., Fox, A., Downer-Hazell, & Wood, C. (Eds.), *World of Viruses*. Lincoln, NE: University of Nebraska Press.

2nd iteration: Phantom Planet

In December, we chose to use *Phantom Planet* as the foundational text (Figure 6; Powell et al., 2012). Whereas *Carnival of Contagion* might be described as fantasy, in that it contains supernatural themes that only loosely reference reality (Laetz & Johnston, 2008), *Phantom Planet* is decidedly science fiction: It uses contemporary understandings of scientific reality to speculate on the future, and moreover, features themes of technology, space, time, and extraterrestrial life, which are characteristic of popular science fiction (Heinlein, 1959). Its story is set in a post-apocalyptic future in which two human scientists from a colony on a different planet visit an Earth, which has since been overtaken by HIV. They dodge zombie-like, HIV-infected humans in order to retrieve a sample of HIV-resistant cells from an abandoned laboratory. With those cells, they plan to develop a cure for HIV in order to save humanity.

In addition to being only 10 pages long compared to the 30-page long *Carnival of Contagion*—a nontrivial detail when we considered the workshop's time constraints, and the need to maintain students' focus

on the science details of the text—our decision to use *Phantom Planet* was grounded in the potential of science fiction writing to engage students' scientific thinking (Jiang & Smith, 2017). Indeed, many science fiction narratives have inspired real-world scientific and technological innovations (e.g., automatic doors, in vitro fertilization, voicemail, bionic limbs).

Another advantage of *Phantom Planet* is that the setting, characters, and story were less defined compared to those in *Carnival of Contagion*. This lent an open-mindedness to the

DAY	ORDER OF ACTIVITIES	INTENDED OUTCOMES
M	• Facilitators welcome students and give an overview of the week. • The whole group plays and discusses Sneeze! • All students complete a pre-test questionnaire. • Students form teams and choose roles. • All students read the comic, Carnival of Contagion. • Whole group introduction to educational games and aligning science learning actions with player actions.	**Deliverable:** Annotations on the comic with initial design ideas specific to chosen team roles. **Learning outcomes:** • Understand team roles. • Lay a foundation for how to design effective games for science learning.
T	• Whole group brainstorming exercise. • Teams brainstorm and document game ideas.	**Deliverable:** Present initial game concept **Learning outcome:** • Learn and practice strategies and best practices for collaborative brainstorming
W	• The whole group plays and discusses Weasels. • Students of the same role meet to receive guidance on role-specific responsibilities to their team's design. • Teams complete brainstorming and documentation. • Teams work on creating a playtestable prototype.	**Deliverables:** At least one game prototype. **Learning outcomes:** • Science Wizards: Learn to recognize the qualities of effective educational games. • Concept Artists: Learn to align gameplay with different kinds of narrative/conflict. • Play Engineers: Learn to quickly prototype through parallel and/or paper prototyping, modding.
TH	• Teams prepare game prototype for playtesting. • Teams write game rules and instructions. • Teams create a game pitch (student-requested topic). • Teams conduct external playtesting of their game prototype with other students. • Teams use playtest feedback to iterate on their prototypes. • Teams playtest and iterate their game again.	**Deliverables:** Completed prototype with documented findings from its playtest complete with playing instructions. **Learning outcomes:** • Learn to recognize core elements of their game in order to provide playing instructions • Learn how to communicate about their game in a sales pitch • Learn and practice accepting critique during playtesting
F	• All students complete post-test questionnaire. • Teams prepare prototypes for game jam, including rule sheets, game boards, and pieces. • Students host game jam for peers at school. • Research team interviews student individuals and groups.	**Deliverables**: Final game design documentation and materials. **Learning outcome:** • Acknowledge and celebrate the week's efforts.

TABLE 2. Overview of the June workshop agenda and intended outcomes.

story that we anticipated would invite youth to devise multiple possible background and extension scenarios via their game designs. Whereas we were initially concerned that using the same foundational narrative would lead the teams toward similar game designs, each team drew on different aspects of it. Some teams used the setting (a post-apocalyptic world), others using the technology (laser weapons and robotic armor), and others drew on the premise of the story (a world is ravaged by disease due to the rampant spread of HIV, and a cure must be found). Each team also diverged in unique ways. While one team chose to set their game in the post-apocalyptic world described in the comic, another chose a Venus colony, and the third chose a town within a forest as their game's setting.

DAY	ORDER OF ACTIVITIES	INTENDED OUTCOMES
M	• Welcome and overview of the week. • Complete pretest questionnaire. • Choose roles and form teams. • Teams rotate between stations (practice brainstorming, play an RPG, read and annotate the comic, *Phantom Planet*).	**Deliverable:** Annotations on the comic with initial design ideas specific to chosen team roles. **Learning outcomes:** • Understand team roles • Understand the basic science of HIV, what RPGs are, and main steps in the design process • Generate initial design ideas for RPG
T	• Play and discuss Sneeze! • Whole group introduction to the role of science fiction in inspiring science innovations. • Whole group review of the science of HIV. • Intro to RPGs and how to incorporate science. • Teams brainstorm and develop initial characters and story premise for their RPGs.	**Deliverable:** Team agreements on RPG characters and premise. **Learning outcomes:** • Apply knowledge of RPGs, science, and worldbuilding to design • Develop team workflow and division of labor
W	• Teams prepare and present their game concepts for whole group feedback. • Whole group introduction to prototyping an RPG (creating maps, characters, game pieces) • Teams rotate between teamwork and RPG play/design consultations with Author 3.	**Deliverable:** Finished character sheets and other game assets, documentation of RPGs story and encounters. **Learning outcomes:** • Apply science knowledge in the game mechanics • Demonstrate understanding of game design concepts and transmedia • Collaborate and divide labor according to role
TH	• Teams complete the first prototypes of their RPGs. • Teams internally playtest their RPGs, and iterate based on outcomes. • Teams playtest and give feedback on other teams' RPGs. • All students complete post-test questionnaire.	**Deliverables:** Game prototypes and design documentation ready for tomorrow's game jam. **Learning outcomes:** • Analyze game for content, learning from playtesting • Evaluate playtesting results for game mechanics, story, and science content to ensure accuracy and quality • Learn how to iterate a design • Work together to complete their design
F	• Teams put finishing touches on their RPG designs. • Each team demonstrates their RPG to their school peers in a fishbowl structure. • Research team interviews student individuals and groups.	**Deliverable**: Final RPG prototypes and design documentation. **Learning outcome:** • Acknowledge and celebrate the week's efforts.

TABLE 3. Overview of the December workshop agenda and intended outcomes.

In addition to the fact that students had recently learned about HIV in their health class, we hoped that in filling in the details of *Phantom Planet*, students would gravitate toward researching new and more advanced science concepts (e.g., how viruses and human immunity evolve over time; how vaccines are developed) as these became relevant to their game designs. However, the fact that the comic's treatment of HIV was superficial and abstracted in dialogue meant that without facilitators' guidance, students struggled to meaningfully incorporate HIV into their own game narratives. Ultimately, students' games built on the notion that HIV compromises the immune system and used their game worlds to imagine possible biological and human impacts of new viruses. Each of the game worlds that the groups built followed a similar trajectory of a disease-impacted world where humans needed to conflict with disease elements in order to survive or flourish. One group created a world where only one criminal organization controlled all of the vaccinations, and the players needed to infiltrate and steal the cure. Another was set in a space colony on Venus, where the players needed to prevent an HIV outbreak. The third was in a small town that had been ravaged by disease, and the players needed to survive and escape while discovering what happened to the town. Each of these three narratives drew from the broader implications of a world that had been greatly impacted by HIV, but they only dealt with the disease itself in indirect ways.

What game genre should we have students design?

In deciding what game genre students would create, we considered students' existing game interests (What would students be excited to learn to create?); the game's alignment with what students are capable of doing (Would it be achievable for novice designers, with some assistance, to bring it to a level of completion that is authentic to the genre?); whether the task of designing the game could be coherently segmented into manageable milestones spread across the week; and whether the process of students designing the game genre involved potential for them to apply scientific knowledge and practices.

1st iteration: Educational games

For the June workshop, we decided to prompt students to design games that would teach players some of the science content covered by the comic. A feature of effective games for learning, which can include any genre of game, is an alignment between the player's in-game actions with actions that are authentic to the domain area (Aleven et al., 2010; Kafai et al., 1998; Plass et al., 2011). For example, a game in which players zap ghosts and intermittently solve fraction problems is one in which the learning actions (solving fractions) are merely appended onto the game actions (zapping ghosts). In contrast, a game in which players must properly slice pizzas to serve a given number of party guests is one in which the game actions (slicing pizzas) are embedded in the learning actions (solving fractions).

Our decision to have students design games for learning was based on multiple reasons. One reason was the promise suggested by previous literature in students learning by designing educational games (e.g., Harel & Papert, 1990; 1991). A second reason was the distributed expertise available among our team members, who were enrolled in, or who took courses in a program on games for learning. A third reason was to promote the authenticity and meaningfulness of the task. That is, we framed the week's activities as a challenge for students to extend the work begun by the comic to educate youth on virology. We told them that after the workshop, we would select promising game designs to develop for public release alongside the published comic.

While this task framing motivated students to engage in the workshop activities, it also proved difficult for us to support their success. This may be due to the complexity of the task: To create an effective educational game requires an understanding of game design, science content, and pedagogical principles, which middle school youth do not necessarily possess (Aleven et al., 2010; Khaled & Vasalou, 2014). Whereas students brought rich prior knowledge of games that they enjoyed playing, few of them had designed games of their own, let alone had sophisticated knowledge of how people learn and how to support it through design.

While students easily recognized and critiqued existing games on their alignment between player actions and learner actions, it was difficult for them to execute that alignment in their own game designs. Instead, students tended to append science topics onto their games, rather than integrate them into their games' mechanics. For example, one group created a board game in which players, infected by measles, roll die to advance along a path and to be first to arrive at a hospital for treatment. In response to facilitators' recommendation that they incorporate more science content, this team added a deck of "fun fact" cards (Figure 7). Players were to select one fun fact to read upon landing on marked squares along the path. Whereas the student-designers undoubtedly learned some science content in researching the science facts, the cards themselves had no purpose in advancing the game. Indeed, their peer playtesters eventually skipped reading the cards in an attempt to move more quickly through gameplay, thus negating their intended learning benefits.

In sum, our experience with the first iteration of our workshop showed that students demonstrated the potential to design educational games, but that supporting their ability to do so required more than the 5 days we had. While we did not expect students' games to approach professional quality, we had hoped that the process of designing them would have at least provided students with rich and engaging content learning opportunities (Harel & Papert, 1991). Instead, the educational game genre, while it lended real-world relevance to the week's challenge, apparently led students to force science content only superficially into their games. We moreover noted that the kinds of games that students created were far from the complex and dynamic narratives typical of the digital games that they reported playing for leisure. Instead, each of the three student teams created board games, which are easier to produce quickly with the resources and skills to which students had access. Several of the students also stated they had made board games in the past, which suggests they were building on their prior knowledge to offload some of the burden of designing a new game. These observations made clear the opportunities that we had missed for engaging students in a task that was both personally motivating and rich with possibilities for deeper learning.

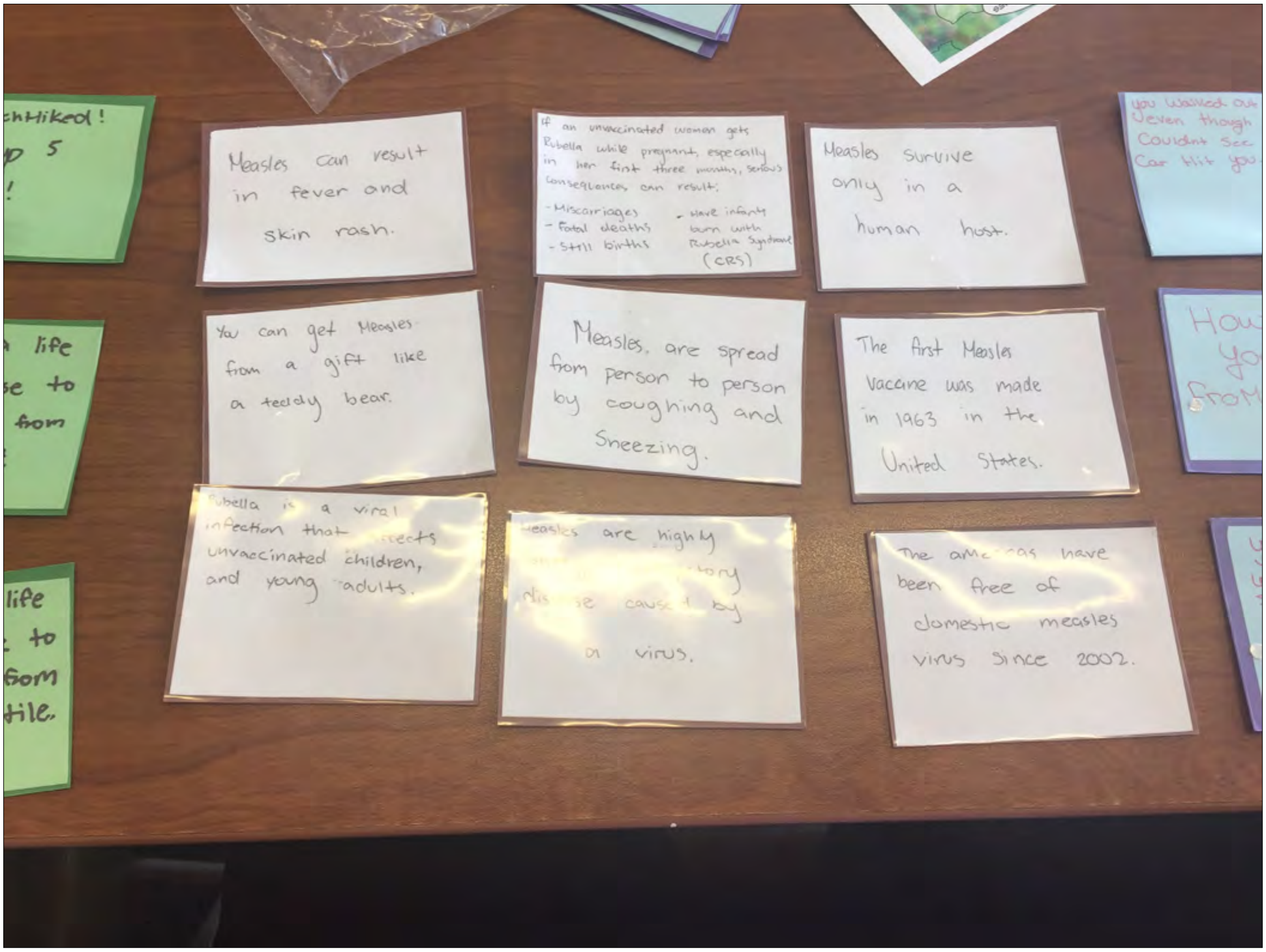


FIGURE 7. "Fun Fact" cards created by one student team in the June workshop in an attempt to incorporate more science into their game.

To address these issues, we determined that our next iteration might either refine our approach to teaching students' educational game design or explore a different genre of game altogether. We decided to pursue the latter and explain our reasons next.

2nd iteration: Tabletop Role-Playing Games (RPGs)

In December, we revisited the workshop's learning goals: Rather than learn to design educational games, we would have students learn to design tabletop role-playing games (RPGs). RPGs are story-based games in which players take on the roles of characters in a fictional narrative. They sit around a table, on which is placed a large map of the game world (Figure 8). Players take turns moving their game pieces across the map and verbally communicating their actions. Meanwhile, one player is the Dungeon Master (DM) and has inside knowledge of the various possible paths, conflicts, and outcomes that depend on players' chosen actions. The DM advances the story by describing situations that players encounter in their progress, relaying the consequences of players' decisions, and as necessary, adapting them in real-time.

Well-known RPGs such as Dungeons & Dragons (Wizards of the Coast RPG Team, 2014a, 2014b) often include high fantasy themes (e.g., sorcery, mythical beasts, kings and queens), in which characters each contribute unique skills in a collaborative quest. We encouraged students to pursue these themes if they desired, and offered examples from the high fantasy genre. We also let students know that science fiction was another direction in which they could take their game designs and one that would build well upon the *Phantom Planet*.

Students' design of an RPG involves three main tasks: (1) building a world that specifies among other things, its geography, the history and cultures of its inhabitants, as well as special laws and customs; (2) creating game characters, including their personalities, traits, and unique abilities; and (3) constructing a story with multiple paths to accommodate the different outcomes of players' decisions.

FIGURE 8. Setup for Author 3's role-playing game, Adventure Quest, which students played in order to experience an example of an RPG. This photo shows the game table from the Dungeon Master's (DM's) perspective. As players move their characters' pieces along the map, the DM refers to notes hidden behind a divider. These notes inform the DM on how to adapt the game's narrative in response to players' decisions while maintaining the narrative's integrity (e.g., when to introduce new characters and key events, how characters should react given different possible player decisions).

Our shift from educational games to RPGs did two things to address the issues we observed in June. First, it allowed us to more closely align the workshop's goals with students' interests. Our conversations with their teacher suggested that the students would be most excited to learn to design a game genre that was different than what they typically make in school (simple tabletop board games), and in which they were moreover highly interested (many were avid viewers of Stranger Things (The Duffer Brothers, 2016), a television series that incorporates RPG themes).

Second, a focus on RPGs allowed us to take advantage of a new team member's (Author 3's) years of experience as a youth educator, RPG designer, and Dungeon Master. Whereas our core team in June had some familiarity with educational games, none were as deeply immersed in the genre as Author 3 was in RPGs. Having him to guide our project team's design and facilitation of the workshop allowed students access to a degree of expert mentorship that we were unable to provide in the workshop's first iteration.

Third, having students design RPGs instead of educational games shifted the focus of the workshop toward storytelling and worldbuilding, and away from the complicated task of aligning learner and player actions. This, we believed, allowed students to engage in the sorts of complex and dynamic narrative-based game making that we knew to characterize some of the games that most interested them.

Fourth, a focus on a narrative-based game genre afforded a clearer path along which students could move from the comic narrative to a game. By asking students to prioritize extending and elaborating on the comic's narrative through their game designs, we strengthened our focus on a core process in transmedia design. This enabled us to better realize and observe the learning opportunities of storytelling and worldbuilding, which were arguably backgrounded in our initial focus on educational games. Even though the workshop's first iteration allowed students to choose their own game genre, these tended to be simple path-based board games. In contrast, the RPG format of our second iteration offered a more complex context for engaging in storytelling and systems thinking, including making and testing predictions and composing logical networks of cause-and-effect (Figure 9). Engineering the potential narratives that may result from players' decisions required students to have a systems-level understanding of the scientific processes involved in their game world. This understanding was expressed in their design decisions, as well as in their game's mechanics. For example, some students decided that when a character becomes infected with a virus, he or she will experience a degree of detriment to their abilities), similar to how viral infections weaken our health in real life. Likewise, some students decided that for viruses in their game world to spread from one host to another would require that both the infected and the new host to experience some damage (i.e., through injury during combat). This game mechanic demonstrates students' knowledge of how certain viruses are transmitted through blood-to-blood contact.

Remaining challenges for balancing science learning and game design

In both iterations, we found it difficult to equalize students' focus on science learning and game making. In contrast to students in June, students in December showed a greater facility with integrating science concepts into their game mechanics. We attribute this finding to the nature of RPGs vs. the relatively simple educational games that students had likely previously encountered, and that may have inspired their own game designs. Yet across both iterations, students' engagement with those science concepts remained superficial (e.g., students could name, but did not appear able to explain the reasons for symptoms of measles). In some cases, their understanding of those concepts was inaccurate.

In December, for instance, one group made an optional boss called 'HIVE' the HIV Monster, which they described as "...a person who mutated into a monster from HIV & animal mix." This idea reflects misunderstandings of how HIV and other diseases work, as well as how mutation and genetics work.

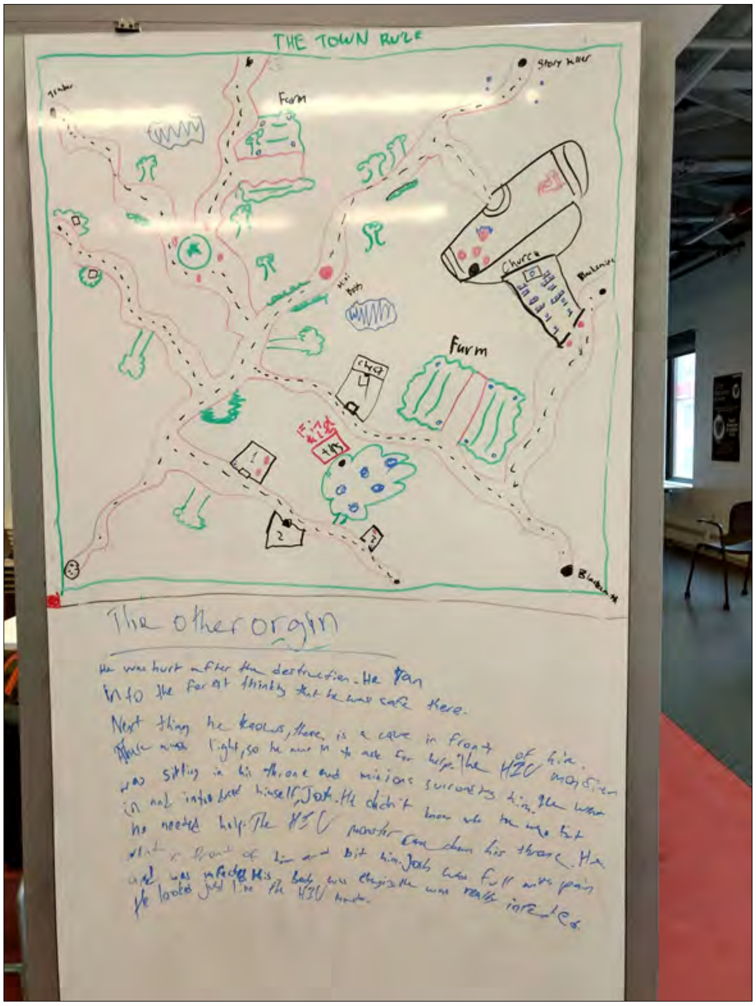


FIGURE 9. One student team's RPG game map and narrative on Thursday of the December workshop.

By the time facilitators raised this issue on Thursday, the team was already invested in the idea, and unwilling to change it. They argued that even though their design did not reflect an accurate conception of the science, their conversations with facilitators about it were evidence that they did in fact understand it. Ultimately, we relented on this issue and allowed them to keep their original design.

It seemed that the students in both iterations were initially more invested in the game aspect than they were in the science aspect of the design challenge. The brevity of their experience in the workshop was not enough to change their initial preferences. We also observed that in both iterations, our decisions regarding the choice of comic and game genre fell short of achieving the balance we sought, but for different reasons. In June, students' superficial treatment of science concepts may be due to the difficulty of coordinating the multiple kinds of knowledge (of science, games, and pedagogy) needed to create good educational games. In December, we might attribute students' superficial treatment of science concepts to the difficulty of designing a world and a narrative that both features fantastical themes and adheres to patterns based on scientific understanding.

GUIDING AUTONOMY

A challenge for us was in creating conditions in which each student would feel autonomous in their design approach, while also offering the scaffolding needed to support them in enacting that autonomy. Some of this scaffolding was to the design process. For example, end-of-day deliverables gave students concrete goals with fixed deadlines toward which to work, even though there were multiple pathways toward which they could reach those goals. Worksheets offered templates to guide students in designing particular aspects (e.g., Figures 10 and 11), or for interacting with their peers in productive ways (e.g., playtesting feedback forms). Each was provided as optional resources rather than as requirements, and it was in fact that case that some students chose to use these, while others chose their own methods.

Next, we discuss how two other approaches we used for guiding students' autonomy—specifying design constraints and coordinating interdependent roles—led to different outcomes.

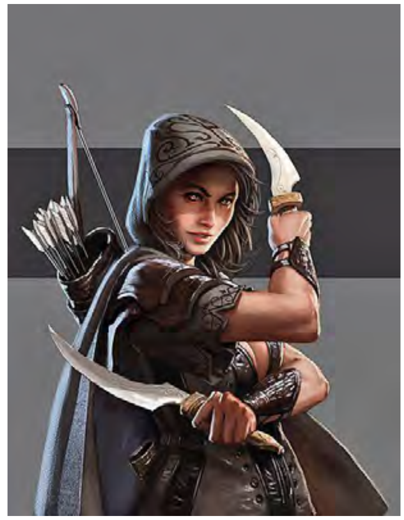
Specifying Design Constraints

In both iterations, we sought to balance the parts of the design challenge in which students would have the most autonomy, and those that we would constrain in order to guide students' thinking and progress through the milestones. One area in which students could exert their autonomy as transmedia game designers was in the content of their games. Students had freedom to choose what aspects of the comic—including its story elements, aesthetic, and science content—to extend through their own game designs. They also had control over the manners by which they would extend the comic's aspects through their games.

We also constrained students to a specific kind of game: Educational games in June, and RPGs in December. We moreover asked students to incorporate the science of viruses in some way, and

specified that the science in their storylines had to be based on current scientific understanding. However, students could take their game narratives in any direction they desired, and indeed, each team spent a great portion of their time devising unique premises for their games.

Cassia, the Rogue



Core:
Health: 15
Armor: 2 (Leather Armor)
Movement: 6 square (30')
Attacks:
Shortsword: Melee, 1d6+3 AND Dagger: Melee, 1d4+3
OR
Shortbow: 30', 1d6+3

Stats:
Strength: +0
Agility: +3
Intelligence: +2
Charisma: +1

Special Abilities:

- **Stealth** - As part of a **move action,** Cassia may roll 1d20+6 to avoid being seen by anyone. Someone looking for her needs to roll a 1d20+Int higher than the Stealth roll to find her. Once she attack or cast a spell, she is no longer stealthed.
    - **Sneak Attack** - Any target whom Cassia attacks from Stealth will take double damage from the attack. This only applies to one attack.
- **Nimble** – Cassia can use Agility instead of Strength for Strength based checks.
- **Quick Reflexes** - Cassia can choose to go first during combat.
- **Nimble Fingers** - Cassia can pick pockets, open locks, and disable traps. As an **action,** she can roll 1d20+Dex vs a target's 1d20+Int, or a trap's DC, Cassia can attempt to use her roguish skills. Failure by 5 or more sets off the trap, breaks the lock, or alerts the pickpocket target.

https://i.pinimg.com/736x/1e/63/ac/1e63ac0c01b87a33ed708a8d73826312--character-ideas-character-inspiration.jpg

FIGURE 10. A character sheet describing the skills, attributes, and personality of a character from the RPG, Adventure Quest, designed by Author 3.

While we established these same constraints at each iteration, they played out in different ways, which we describe in the following sections.

1st iteration: How guidelines constrained students' ideas.

At the first iteration in June, we noticed that students generally only used the science from the comic (a list of measles symptoms), and did not develop it beyond the way it was originally presented. They left the comic's story elements largely untouched, and instead invented new stories to layer over their games' mechanics. This outcome may be due to the choice to constrain students' to designing educational games. As mentioned earlier, this genre can be difficult for novices as it requires designers to both have and to coordinate diverse kinds of knowledge. At the same time, if students had had simple, preconceived notions of educational games (e.g., quiz-style or flashcard-based games), they may have felt limited, both in the ways that they could draw upon and incorporate the comic's narrative and in the ways that science would be represented in a game.

2nd iteration: How guidelines shifted students' focus away from our intended outcome.

In contrast, we observed students designing RPGs during the second iteration in December to draw more intentionally from the comic's story elements, including its premise, its technological artifacts (e.g., robotic spacesuits and laser weapons), and its setting. Their inclusion of science, while not approaching the level of mechanistic explanation expected by formal science education standards, did indeed extend the science presented in the comic (the notion that HIV weakens the immune system and makes one susceptible to new viral infections). This observation may be attributed to the fact that designing RPGs is as much about designing narratives as it is about designing the mechanics of players' interactions within those narratives. Thus the constraint that we imposed on students to design an RPG encouraged them to incorporate the comic's narrative into their games and to thus produce games more strongly grounded in the transmedia tradition.

In some cases, however, we noticed that the game genre that encouraged students to draw more intentionally from the comic's narrative also posed potential threats to our intended outcomes. Perhaps inspired by the genre, students

GAURDIAN ANGEL - lab experiment

Character Name

Core:
Health: 70
Armor: 2
Movement: 6
Attacks:

Lucky shot D1UA(D20)

Hevenly strike D5 (D6x2)

Quick stich D5 1(D20)

Flying drop kick D5(D20

Stats: Assign core stats to your character. Each character gets +3, +2, +1, and +0 to distribute amongst their stats.
Strength:
Agility: 4
Intelligence: 1
Charisma: 2

Special Abilities: Each character gets 3 Special Abilities that they can use during the adventure. At least one ability must science-based.

1. Flying drop kick (kick someone Before Anyone moves)
2. Hevenly strike (hit from Above on Your turn not wasting your Actions)
3. Quick stich (Stich Someone quickly wen youre not in combat)

Backstory: Write a backstory for this character that explains why curing HIV is important to them.

The angel is the hiv monsters brother. he was involved with helping his brother by giving him T-cells. His DNA was combined with birds, to produce more T-cells, to give to the hiv monster. mutation acord in the DNA, mutating bones, organs, and matabilism. Feathers grew from outgrowths of skin. This was a 12 year process

FIGURE 11. A character sheet filled out by a student team in December, describing one of their RPG characters.

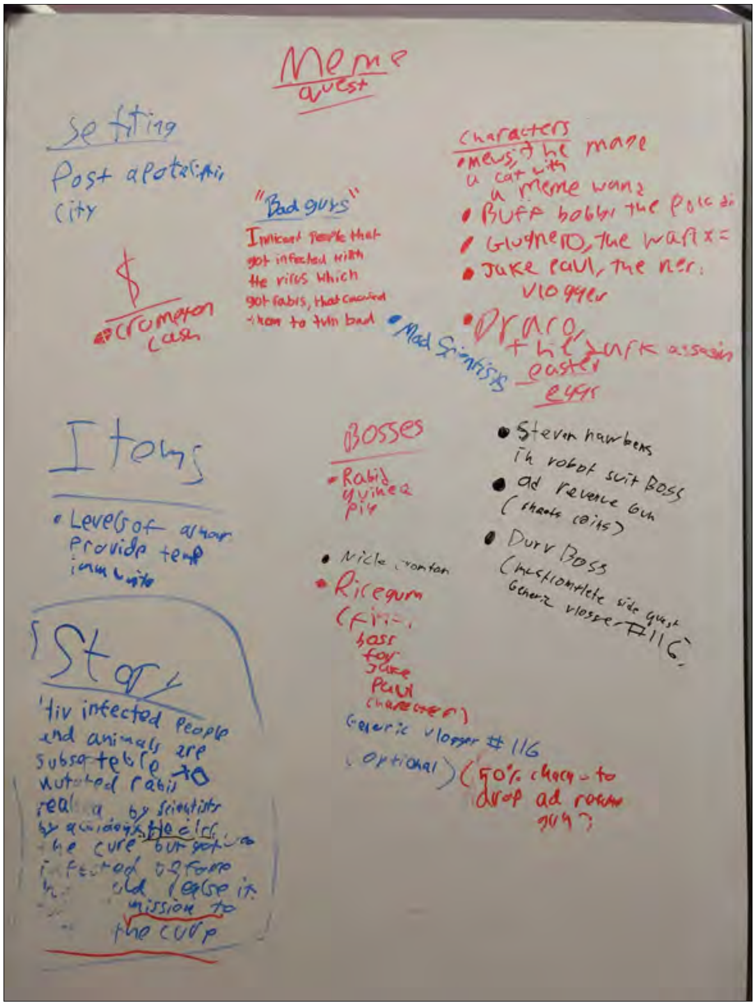


FIGURE 12. Notes from one student team's brainstorming session in December, which reflects the meme theme they had devised for their RPG.

drew heavily from themes of related commercial games and popular culture with which they were familiar. For example, one student team in December strayed far from the comic's narrative when in their brainstorming sessions, they zeroed in on internet memes as the central theme of their game world: characters bearing the names of famous memes, and one of the weapons they defined as a "meme gun" (Figure 12). Facilitators eventually advised the team to downplay the meme theme as it had caused them to diverge too far from the foundational narrative, and was distracting the team from attending to the key elements yet to be designed in their RPGs.

We might have better guided students' RPG designs along the direction that we intended by providing them with more science-relevant examples of RPGs. Instead, the high-fantasy RPG example created by Author 3, while it was useful for illustrating basic RPG design, did not exemplify a design grounded in science. This had the effect of encouraging students to freely generate far-ranging ideas but then leaving them with the challenging task of figuring out how to ground those ideas in science.

In all, these examples highlight the value of defining clear boundaries in students' design processes in order to constrain the space of possibilities, and to ensure that students' designs remained within the overarching theme of our workshop. At the same time, our experiences remind us that we cannot expect consistent outcomes from our design decisions around any one component of a learning environment, as each is in constant dynamic interaction with the other.

Coordinating Interdependence

How to coordinate students' collaboration was one of our project team's major design considerations. We were mindful of the need for students to work efficiently in the week that we had together. We also wanted to give each student the chance to feel autonomous in their decisions, to grow in expertise of their choice, and to successfully draw on their teammates' contributions to create something larger than would otherwise be possible.

Our approach to these objectives was to define three interdependent team roles. One student team member would be responsible for creating the game mechanics, another for the visual and narrative elements, and the third for researching and incorporating science content (Table 4). In our vision, students of a particular role would lead the vision and any research required of their role, but would only be able to realize that vision by collaborating with their partners in the other roles.

1st iteration: Assigned roles

The teacher formed student teams before the beginning of our June workshop, based on whom she thought would work best together. Once in their groups, students divided role assignments between them: Science Wizards, would be responsible for researching and incorporating science concepts, Concept Artists would direct the narrative and visual aesthetics of the game, and Play Engineers would focus on working out the game's mechanics.

We incorporated various activities to help reinforce students' roles. For example, we scheduled expert workshops throughout the week, during which students of the same role from across teams would gather together for role-specific guidance. We also requested role-specific deliverables following some of the activities. In reading the comic, for instance, Science Wizards were to identify science concepts, Concept Artists were to note interesting aesthetic and narrative themes, and Play Engineers were to identify relevant action verbs to inspire game mechanics.

In spite of us informing the students of the purpose and responsibilities that each role entailed, and our attempts to support them in executing their role-specific tasks, these role assignments ultimately did not persist through the rest of the week. One reason is that due to activities that ran longer than anticipated, we had to cancel one of the scheduled expert workshops in order to move students along in completing their milestones. Another reason is that our framing of the roles became distorted through miscommunication. This mattered more or less, depending on the team's existing rapport. For example, one team worked well together in delegating and completing tasks based on priority rather than on specialized responsibility. However, one student in another group ultimately dominated his team by directing the design vision and completing most of the tasks himself without consulting his teammates.

Our failure to clearly frame the roles, and to provide consistent support for students to carry out those roles, meant that students began to see them as a way to divide labor among teammates, rather than as a chance for each member to integrate unique contributions. Unfortunately, this decreased students' autonomy and, in some cases, led to group conflict.

2nd iteration: Flexible roles

Given the challenges we experienced in June, we refined our approach to coordinating students' interdependent roles during the December workshop. Doing so involved several changes. First, rather than have a teacher assign student teams beforehand, we first introduced students to the possible roles by highlighting the skills and interests associated with each. We then invited students to choose a role based on what they considered to be the best fit. For example, Worldbuilder was described as a role for those who enjoyed inventing stories; Science Wizard suited those who enjoyed asking "why" questions and researching information, and Game Engineer was for those who enjoyed working out details and thinking of the effects of their choices on the whole experience.

Next, we had students self-organize into three groups by finding 3-4 partners with complementary roles. Because there were three roles and at least four members per group, one of the roles was either represented by up to two group members, or the fourth group member could choose to be flexible across roles and to contribute in the manner they wished.

In contrast to June, this approach allowed students to first choose the role with which they self-identified, and second, with which of their peers they enjoyed working.

During the first day, students of the same role rotated as expert groups between facilitator-led stations, in which they were guided in noticing details and asking questions that would help them to contribute in their roles when they later rejoined their teams. In one station, students read the comic and discussed how to extract ideas from it that would either help to paint a setting and story (Worldbuilders), focus in on a set of relevant science concepts (Science Wizards), or consider interesting events and interactions that might occur in the narrative of their game (Game Engineers). Similarly, a second station led students through playing an existing RPG. Here, Author 3 pointed out to students the aspects of the RPG that would be directed by each role, and the manners in which they would need to coordinate with their partners in order to realize their ideas in their designs. A third station led students through best practices in brainstorming, with an emphasis on valuing and building upon others' ideas.

Our intention with this approach to roles was for students to both feel a sense of autonomy and accountability in their abilities to make unique contributions to their team's vision, while also having a network of peers outside of their team

ROLE (JUNE)	ROLE DESCRIPTION (JUNE)	ROLE (DEC)	ROLE DESCRIPTION (DEC)
Concept Artist	Ensures that the game draws appropriately from elements of the comic, crafts the game narrative, and develops a visual style.	**Worldbuilder**	Designs all elements of the environment in which the game takes place: its landscape, institutions, cultures, and characters.
Play Engineer	Designs mechanics and ensures that the game is both fun and sufficiently aligned with the visions and ideas set by the Concept Artist and Science Wizard.	**Game Engineer**	Crafts the events of the story, and the encounters between the characters and the world.
Science Wizard	Integrates science into the game, drawing from content taught in the comic and any necessary research. Makes sure that the science in the game is accurate.	**Science Wizard**	Integrates science into the world and in all encounters. Makes sure that the science is accurate and that it drives the narrative in compelling ways.

TABLE 4. Overview of students' roles in June and December workshops.

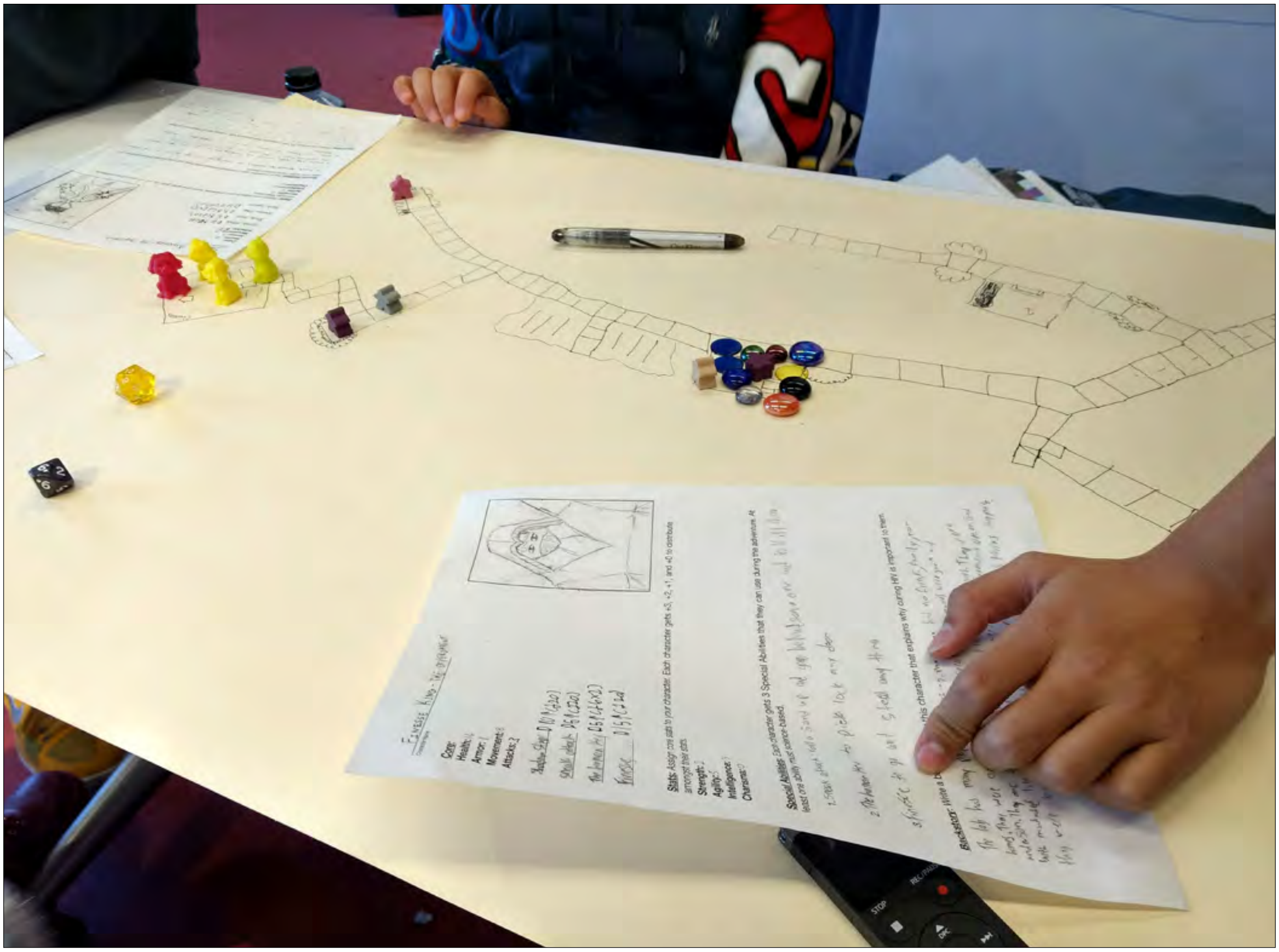


FIGURE 13. One student team's RPG map from the December workshop. The map was drawn by the Dungeon Master as the game unfolded during the game jam on the final day.

with whom they might share strategies for addressing issues specific to their roles.

Clear specification of responsibilities through these defined roles was critical in providing a conceptual framework for how the design process should unfold, and guidance on how students might coordinate their efforts. Students also found opportunities to grow into these roles for their own and their team's benefit. For example, one student, whose team experienced some difficulty staying on track, referred back to his responsibilities as Science Wizard to maintain his own focus. This ultimately helped the rest of his group to achieve their milestones.

Worldbuilders from two of the three teams eventually served as Dungeon Masters during playtesting, and the final day's game jam. Although the responsibility of Dungeon Master was not explicitly assigned to any of the three roles, the Worldbuilders' deep knowledge of their team's game world and characters, and their pre-existing interests in storytelling, prepared them to determine the narrative's direction as their players explored their game's world (Figure 13).

While defining roles was helpful for reinforcing students' identities, it was also useful to keep them flexible. In point of fact, students from two of the three groups ultimately reallocated responsibilities among teammates based on the tasks each felt more comfortable doing, instead of what their initial roles specified. This, to us, this illustrates the success of designing flexible roles in giving students the ability to moderate one's own identity in a dynamic context, by choosing which contributions to make is an important part of being autonomous.

CONTEXTUAL MEDIATORS OF DESIGN

Whereas each of our design decisions had intended outcomes, we observed several factors outside of our direct control that impacted those outcomes in sometimes unanticipated ways. These factors include students' identities and peer relations, our team's own expertise, and the degree to which the accompanying teachers also participated.

Students' identities and peer relations

In our aim to engineer productive social interactions among the students, we sought to recognize and allow students to build upon their own identities through their choice of role and teammates (Table 4). In terms of skill- and interest-related identities, this collaborative structure was fairly successful.

Students who on their pre-tests, indicated that they self-identified as either gamers or with science, were indeed committed to their chosen roles as Game Engineers and Science Wizards, respectively. The flexibility of roles, moreover recognized the fluidity of students' identities. By the end, several of the students made substantial contributions in roles that they had not initially chosen, as they became interested in the work. In other cases, students switched roles entirely when, as one student described, "I felt that someone else was better than me at [the role I initially chose]." In June, one student, who typically struggled in classroom settings, surprised his teachers with his ability to seek input and organize his team's efforts, eventually becoming his team's leader.

The fact that there was such diversity in knowledge and abilities within student teams meant that each team experience differed. In December, one highly collaborative team managed to create a complex and engaging game but struggled to make it more scientific. Meanwhile, another team experienced few issues in incorporating science into their game but struggled to collaborate effectively and efficiently to meet their deadlines.

In terms of personal relations, however, our collaborative structure could not have addressed the occasional social conflict that certain teams experienced. For instance, in June, as described earlier, one student ended up dominating his team and took control of all design decisions rather than create space for his teammates to contribute. While we had adapted our approach to emphasizing interdependent team roles by the second iteration, it is possible that had a student with an equally strong personality participated again, and we may have nevertheless observed a similar outcome.

Also, as described earlier, we had students in December form their own teams to ensure that they would enjoy working with their teammates. However, some shifting of team membership was necessary. In one case, it was revealed by the teacher that two students had personal differences that would affect their work. Both of these students welcomed the opportunity to separate into different groups, and to take on flexible roles to complement their new team. In another case, one student had gradually disinvested himself from the team's work and was actively disturbing his partners' progress. A breaking point occurred early in the week when Author 3 was leading this students' team in playing a sample RPG adventure game. On his turn, the student decided to kill a potentially helpful goblin character, in spite of his teammates voting to befriend it. As an RPG is intended to be a collaborative effort in unfolding a story through players' decisions, this student's rogue behavior was a genuine betrayal to his team. The student became increasingly isolated from his partners, who in anger, told him: "You're the worst team member ever!" "Nobody wants you on our team anymore", "Selfish", "I'm done with you." Eventually, the student's continued disruption of the focus of his teammates (one of whom expressed in frustration at his partner's behavior, "I just want to get this done.") caused his teacher to dismiss him from attending the rest of the week's activities. In his absence, progress was relatively smooth for his team, who ended up producing a highly successful game by the week's end.

Interpersonal conflict is to be expected in any kind of teamwork. We observed such conflict in minor disagreements within student teams over design decisions (e.g., a character's name), as well as in ways that significantly impacted a team's progress, as described earlier. Our experiences have reminded us that as designers of learning environments, we can never ensure universally successful collaboration as an outcome. Rather, we can only create conditions for making this outcome more likely. The uncertainty with which individual participants will interact on a personal level emphasizes the importance of not only allowing students a degree of flexibility but also of creating redundancy in students' interdependent roles (e.g., by having 4-5 group members share 3 roles). This way, student team members can fluidly move between roles, and if one member were to leave, the rest of the team could self-organize to cover his or her role. Given that difficulties in collaboration are bound to happen, facilitators can ensure that these become teachable moments: From them, students can learn that there are real consequences to their actions.

Project Team Expertise

The composition of our own project team had a critical role both in determining the focus and enactment of our workshop. In general, members of our design team were Masters and Ph.D. students, who at the time were studying in NYU's programs for education, games for learning, and digital media design for learning. Each member was drawn to participate due to personal as well as research and design interests in games for learning, comic book culture, and design-based learning environments. Each member also had individual goals that differed depending on their prior experiences, career track, and status. For example, Masters students had a desire to apply their professional and developing expertise in design thinking, game design, and youth science education. Doctoral students meanwhile developed and focused on research questions related to their individual research programs. The diverse goals and experiences of our project team members not only influenced the overall focus of our workshop, but also the ways that we would run specific activities.

In June, for example, our project team had collective experience in critiquing educational game designs, and one of us had previously taught design thinking to college-level learners. However, none of us had deep, practical expertise in game design. Moreover, one project member who did have prior professional experiences working with middle school learners (Author 2) was only able to attend portions of the entire workshop. To account for these shortcomings, we invited guest experts (students and faculty from our program) to lead sessions on such topics as brainstorming and prototyping. These guests likely had a positive effect in heightening the stakes for students' work in their additional roles as external audiences of students' work in progress (cf. Smith & Shen, 2017). However, it is also possible that the guest sessions removed some of the fluidity and sense of continuity in students' experiences of the design process during their participation, particularly given the short length of the workshop.

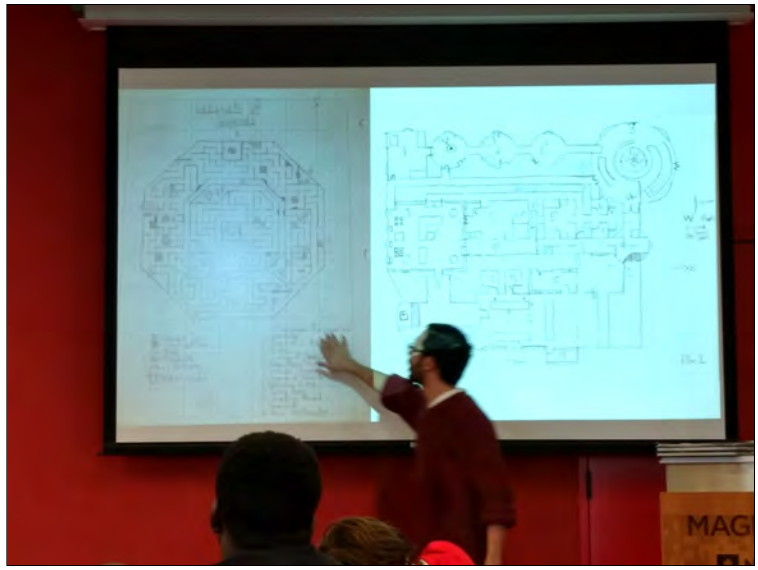


FIGURE 14. Author 3 shows students maps created for existing RPGs, on Wednesday of the December workshop.

By the second iteration, our project team had changed: Author 1, Author 2, and Author 4 remained from the first iteration, while Author 3 and two other Masters students joined for the second iteration. Because Author 1 continued as project leader, our process for planning and facilitating the workshops, in spite of our changed membership, remained largely the same. We continued to meet weekly to discuss ideas in progress; we continued to document and refine our plans over shared Google documents. Having already created a template for a daily internal agenda during our first iteration, we were able to more quickly work toward specifying one for our second iteration.

However, the interests and expertise of our newest project member, Author 3, caused a shift in our research and design direction. Author 3 had extensive prior experience as a Dungeon Master and RPG designer, as well as being a former school teacher and youth leader. We saw an opportunity to build on his skill set in order to explore an environment that we were ill-equipped to create in our first iteration. He contributed examples from his personal projects, and activities that he had used in his experiences as a Dungeon Master and educator, to create our June workshop. During the June workshop itself, Author 3 also became a key mentor and resource for students (Figure 14). Just as the students, Author 3 self-identified as a gamer. He developed a rapport with the students through a shared language of games, which not all facilitators had. As a result, students approached Author 3 for feedback on their designers and for further resources, whereas they approached other facilitators for science questions or clarification on design requirements, among other concerns.

Two other members who had remained from our June project team also brought strong voices of leadership to our second iteration in December: Author 4, who had maintained her internship in our participating school, and who, by the time of our second workshop iteration, had grown even more familiar with many of the students; and Author 2, a former middle school teacher and curriculum mentor. Each of these project team members was critical in helping to orchestrate students' movement within and between activities, and to generally ensure that they were on task and on track.

These experiences highlight the value, in designing an interdisciplinary learning environment such as ours, of creating a team in which members offer complementary expertise and can help to shape each necessary component. Our experiences also highlight the value of making facilitators' identities visible to students, particularly for strengthening the facilitators' roles as anchors in students' conceptual and practical work throughout the week.

Teacher involvement

As described earlier, student participants in both of the workshops that we hosted were accompanied by at least one teacher from their school. This teacher had a supervisory role, as was required of every workshop hosted by industry partners. The degree to which our supervising teachers involved themselves in our workshop activities was up to their own choice, and not due to any explicit request or mediation on our part. Teachers' contrasting approaches to involvement between iterations appeared to impact students' experiences.

In June, the accompanying teacher was a former high school teacher and had just completed her first year of teaching middle school. She maintained a physical distance from the students and did not participate in any of the workshop's activities. Instead, she played the role of chaperone as she accompanied the students to and from the workshop and at lunchtime. Meanwhile, the school's science director, who joined during the first two days of our June workshop, took a heavy-handed approach to overseeing and directing one student team's work. While his involvement ensured on-task contributions from all student team members (who were otherwise dominated by one team member in the science director's absence), it also minimized the opportunity for those students to express agency, as we had intended.

A different teacher accompanied the students in December. During our planning phase, she expressed to us her desire to learn alongside her students and did indeed participate as an integral member of each student group. For example, she helped students to conduct internet research on science information they needed to include in their game narratives, and she also playtested and gave feedback on students' games. Importantly, the teacher moderated students' behaviors and intervened in one case to dismiss one student whose off-task behavior was disrupting his team's focus. This teacher's dual role as participant and authority figure complemented and expanded our own team of facilitators. She helped to keep students' behaviors in check, as well as to create a lighthearted and collaborative atmosphere.

DESIGN INSIGHTS AND IMPLICATIONS FOR COLLABORATIVE TRANSMEDIA GAME DESIGN FOR LEARNING

We had set out to explore transmedia game design as an environment for supporting students' developing dispositions in science and design. Through iterations on a workshop, we refined our approach to integrating science learning with students' interest in games and comics, and to incorporating guidance for youth's autonomy within collaborative design. Our experiences also highlight the unique scaffolding issues in science learning, game design, and collaborative design; and the challenges of combining each into a coherent week-long experience. In this section, we reflect on lessons from our design approach with respect to supporting collaborative learning and science learning, and the promise of transmedia game design.

What did we learn about collaborative design?

Our experiences illustrate the importance of building in flexible structures for peer interaction. The roles we had refined by the second iteration provided students with clear responsibilities to drive their participation, while also creating room for individuals to make autonomous decisions and space that recognized the fluidity of their identities. We believe that these fluid structures ultimately helped to create more robust design teams, capable of adapting to changes in membership, and in individual team members' interests.

From our observations and student interviews, students were most articulate in identifying the collaborative and design skills they had learned during the week, with some students pointing to the importance of "listening to other ideas" and the "planning and brainstorming" processes as skills they anticipate finding useful in their future careers. Others described specific team strategies they had found to be successful, such as to "Hold votes to make decisions."

What did we learn about science learning?

Students appeared less able to articulate the science they had learned from the experience. Indeed, conceptual knowledge proved challenging for us to measure through a traditional assessment approach. In both iterations of the workshop, students' responses to the science content items of our assessment showed little change from pre to post. For the most part, they continued to give superficial explanations, if any, of (for example) how a virus enters the body and how the body responds. Anecdotally, some students admitted to not having learned much about the science of the focal virus, nor about its related concepts (e.g., innate immunity, the causes of symptoms).

However, rather than see this as a failure of our workshop to teach science, it may be a failure of our assessment to sufficiently capture what students actually learned about science. Prior research points to the process rather than the product of design as the location of meaningful learning (Harel & Papert, 1991). In a game design setting, learning is visible in students' game design iterations (Hovey, Matuk & Hurwich, 2018). Accordingly, we did observe science learning in other more subtle ways, particularly in December's iteration. For example, one team, inspired by the robotic exosuits featured in *Phantom Planet*, set their RPG on a space station on Venus. Their design decision led them to research Venus' gravitational constant and the chemistry of its atmosphere, topics that extended the science beyond the science of viruses that we had initially anticipated. Likewise, another team was prompted to research the science behind bird evolution and DNA recombination in order to justify their choice to have a winged character in their game (Figure 11). Our study of this student team's process showed how the performative storytelling practices inherent in worldbuilding also encouraged practices that are critical to scientific explanation, such as giving and receiving peer feedback and integrating new information into existing ideas (Matuk, Hurwich & Amato, 2019). Such examples point to the promise of transmedia game design for creating rich and unlikely opportunities for learning.

What did we learn about the promise of transmedia game design for learning?

Arguably, our workshop did not succeed in imparting specific transmedia practices, nor did students' games explicitly reflect principles of transmedia design. In our June iteration, students' games did not draw at all on the comic's story, and only minimally on the science of this foundational narrative. By December, we did observe students' games to extend certain story elements of the comic. This was likely due to our different choice of comic and game genre, and their influence on students' thinking, as discussed earlier. For example, students designed RPG characters based on those in *Phantom Planet*, as members of technologically advanced, post-apocalyptic civilizations, who sported spacesuits or robotic exoskeletons not unlike the ones from the comic (Figure 6, bottom left panel). The main narratives if students' games, however, diverged farther from the foundational text than what is traditionally observed in transmedia franchises. Indeed, none of the student teams used the exact setting from the comic, but instead either set their games in a town, orbiting Venus or in a scientific lab in a different city. While at least one character in every party was a scientist, as were the characters in the comic, students also included characters such as commanders, doctors, scouts, and medics. Thus, while students' games were not recognizable as existing in the same world as the comic, as would have been the case with a true transmedia project, we felt that beginning with transmedia as a general design approach allowed us to integrate game design, science, and systems thinking through narrative, into a coherent learning experience. The comic and the task to design a game led to students' deeper engagement with each of science, design, collaboration, and systems thinking through game making and worldbuilding.

CONCLUSIONS AND FUTURE ITERATIONS

Our goal with this workshop was to create a learning environment where students had the necessary scaffolding to be successful, but enough freedom to support agency and drive creativity through a design process in which they would learn science content.

Our experiences highlight the importance of multidisciplinary game design activities of having a guiding framework that accounts for the cognitive and affective components of expert dispositions. Our own approaches demonstrated varying success toward both of these goals, particularly given the diverse prior experiences that students brought: rich prior knowledge of and experiences with games; initial misconceptions of science; and preconceptions of what

1ST ITERATION: JUNE 2017	2ND ITERATION: DECEMBER 2017	DESIGN IMPLICATIONS
DESIGN GOAL. To balance the focus between learning science content and engaging in game design.		
STRATEGY **Foundational narrative:** *Carnival of Contagion* (~30pp), which tells of the shared dream of a group of unvaccinated youth infected by measles. It covers the symptoms of measles and the importance of vaccination. **Game genre:** Game for science learning. **Activities:** Centered on how to design games that explicitly teach science content to their players. **OUTCOMES** The science in students' games drew directly from the comic without elaborating or extending it. None of the students' games drew on the comic's story elements.	**STRATEGY** Foundational narrative: *Phantom Planet* (10pp). This comic's story imagines a futuristic world ravaged by HIV. It covers the concept of HIV-resistant cells. **Game genre:** Tabletop Role-Playing Game (RPG). **Activities:** Supported students in building a world that incorporated themes from the comic, and that was grounded in scientifically normative ideas. **OUTCOMES** Students' RPGs drew upon elements of the comic's story but diverged far from the original narrative as students incorporated themes from beyond the comic that interested them. Science content was superficially present in students' RPGs, and primarily driven by their game design decisions. The science also extended beyond virology to other topics as these became relevant, including hemorrhagic diseases, robotics, and the planet Venus.	The choice of foundational narrative and game genre used in transmedia game design influence what students create, and what learning experiences they take away from it. Open-ended stories such as the one in *Phantom Planet*, and narrative-based game genre such as RPGs, allow students to engage deeply in worldbuilding. This offers opportunities for students to build on their existing interests. As well, through students' design decisions, they can go deep into topics in ways that are authentic to their goals. This can promote learning in unlikely places.

TABLE 5. Major design decisions and outcomes between the first and second iterations of the workshop. (continued on next page)

1ST ITERATION: JUNE 2017	2ND ITERATION: DECEMBER 2017	DESIGN IMPLICATIONS
Design goal: To balance student autonomy with necessary guidance.		
STRATEGY **Design constraints:** We encouraged students to choose which genre of game to create, with the constraint that it should teach something about the science from the comic. We led students in playing and discussing educational games that we had designed, and also had them critique other existing educational games. Facilitators, moreover, prompted students to increase the emphasis on science in their own games when it was evident that they were not doing so. **OUTCOMES** Each of the students' games took the form of simple tabletop and path-based board games. Whereas students could identify what made existing games for learning good vs. poor, they struggled to embody those qualities in their own games and ended up tacking on science content without integrating it into their games' mechanics.	**STRATEGY** **Design constraints:** We led all students in designing tabletop RPGs. We specified that each game should draw on story elements from the comic, and be based in scientifically normative ideas. Beyond this, students had the freedom to take their RPG in any direction they desired. A main feature of the workshop was an RPG designed by Author 3, which served as many students' first experiences playing an RPG, and an example to which they returned during their own design process. **OUTCOMES** Students readily and deeply engaged in world-building and character creation. In general, they required prompting to attend to the science content. While their games ranged widely in the science topics addressed, they did not go deeply into mechanistic detail or scientific explanation.	Different game genres require coordinating different sets of skills, some of which are more or less challenging for students. Source material, design tools, and guidance needs to be highly structured, with fixed creative outlets where students can include learning content.
STRATEGY **Coordinating interdependence:** Students were assigned to teams by their teacher, and then each chose from the roles of Science Wizard, Play Engineer, and Concept Artist. Special sessions for members of the same role were planned but not prioritized. As a result, these were dropped when the schedule had to be adjusted during enactment. **OUTCOMES** Roles were generally misinterpreted, and their boundaries became muddled over time. Teams eventually found their own ways to work together to reach their milestones, although some less successfully than others.	**STRATEGY** **Coordinating interdependence:** Students first selected one of the roles of Science Wizard, Game Engineer, and Worldbuilder. A fourth role could be flexible across the other roles. Next, students formed teams with members of complementary roles. Students of the same role grouped together for activities on the first day, which served to lay a foundation for their role-specific responsibilities to their teams. **OUTCOMES** Roles served to anchor the focus of some students when their teammates behaved off-task. By the end of the week, some students had played more than one role, and some had switched roles entirely.	Well-defined roles can help to guide the process of an open-ended design task and coordinated teamwork. At the same time, flexibility in assigned responsibilities can allow students autonomy in managing their own shifting identities as they learn more about their own and their teammates' abilities.

TABLE 5 (CONT). Major design decisions and outcomes between the first and second iterations of the workshop.

makes a designed experience both fun and related to science.

We have illustrated how priorities emerged, shifted, and transformed through our enactment of a youth game design workshop, and have reflected on how to create a learning experience that supports collaboration and autonomy within the constraints of a school-like context. Our insights, summarized in Table 5, emphasize the challenges in balancing support for science learning, game design, and collaborative skills, particularly given realistic time constraints and students' various starting points with different domain knowledge and skills. Questions raised by our experiences will inform the design of other similar environments.

As our design team evolves, it will be important for us to refine our scaffolds. Identifying successful templates and resources to guide students' work, as well as processes for advising on each of the conceptual and collaborative challenges that we anticipate students will experience, will help new team members take on the role of facilitator. New team members will inevitably suggest further new foci and directions, based on the expertise they bring with them.

Our experiences suggest a number of improvements, as well as new approaches to explore in future iterations of this workshop. First, while we found that giving students room to diverge from transmedia standards was informative for us in exploring the potential of transmedia as a learning environment, we might see what further advantages present themselves through more explicit emphasis on transmedia practices.

Second, we might continue to explore ways to strengthen students' interdependent roles within teams, as well as what can be learned from students across other teams. Through more focused expert workshops on key design issues that arise during the week, students of the same role may both learn from one another's solutions, and then bring new ideas back to their respective teams. Through further iteration, we might begin to identify and anticipate the challenges to be addressed, and so be more intentional about supporting both individual and community goals.

Finally, we wish to explore the role of peer mentors in collaborative design. High school or undergraduate students, whom we may train in advance as science-based game designers, might be embedded within middle school design teams as older, more experienced peers. Particularly given the focus of this workshop on media genres commonly associated with youth culture (games and comic books), we would be interested in understanding and designing environments that include peers who share similar identities and affinities, but that bring different experiences and abilities, in order to enrich everyone's learning experiences.

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