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Game-Based Health Education: The Case of Hexacago Health Academy

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ABSTRACT: It is a well-documented fact that women and minorities are currently underrepresented in STEM higher education degree programs and careers. As an outreach measure to these populations, we established the Hexacago Health Academy (HHA), an ongoing summer program. Structured as an informal learning environment with a strong youth initiated mentoring component, HHA uses game-based learning as both a means of health education and stimulating interest in careers in medicine among adolescents from underrepresented minority populations. In this article, we describe the 2015 session of the Hexacago Health Academy, which focused on the topic of sexual and reproductive health (SRH). The overall structure of HHA, with its dual focus on game design and enabling youth interaction with science and health professionals, is discussed. Qualitative data from the 24 youths that participated in the 2015 summer session was collected. Results indicated that the initial session of HHA succeeded in its goals of developing critical thinking skills among participants, encouraging teamwork, broadening understanding of the health sciences, and encouraging risk-taking in education. The overall potential efficacy of informal learning environments that use game design as a core component to stimulate interest in STEM fields is discussed.

INTRODUCTION

Increasingly, scholars and policymakers in the United States (U.S.) are recognizing the importance of having a diverse, globally competitive workforce in the fields of science, technology, engineering and mathematics (STEM) (Chubin et al., 2005; Kuenzi, 2008; National Science Foundation [NSF], 2010) . However, an imbalance exists in the demographic and gender makeup of STEM professionals, from scientists to engineers to physicians, dentists, and nurses (Sullivan Commission, 2004; Landivar, 2013). Concerns that the nation is not preparing an adequate number of students, educators and practitioners in STEM fields has led to calls for reform in STEM education for American students (Kuenzi, et al,, 2006), who continue to fall below national standards (National Assessment of Education Progress [NAEP], 2015) as well as behind their peers abroad (Program for International Student Assessment [PISA], 2015) in these areas of study.

Building up STEM talent in the U.S. will in part mean ramping up recruitment and training of those with promising potential who lack access to opportunities for advancement within these fields (Subotnik et al., 2009). There will be a need to create and draw from the talent pool of women and minorities. Both groups are currently underrepresented in STEM higher education degree programs and careers. In the United States, African Americans, Hispanics, and Native Americans earn fewer than 15% of undergraduate degrees in engineering, math, and the physical and biological sciences (NSF, 2017). Similarly, women, particularly minority women, obtain much lower level degrees in these fields than men (NSF, 2017). Additionally, both groups experience higher attrition rates from STEM fields (NSF, 2010).

A number of factors limit the recruitment and retention of these underrepresented groups in STEM fields, including minimal exposure to or interaction with people who currently work in these fields (Koch et al., 2010; United State Department of Education Office of Vocational and Adult Education, 2012), lack of mentors with whom they can identify (Weisman and Gottfredson, 2001; NSF, 2010), and negative stereotypes or diminished expectations for their intellect, abilities, and performance (Fisher et al., 2000; Brown and Leaper, 2010; Grossman and Porche, 2014). As a result, even high-performing students from underrepresented groups with initial interest in STEM often do not pursue these disciplines.

Formal learning environments such as schools have been limited in addressing these barriers to STEM interest and advancement among underrepresented youth (Denson et al., 2013). However, a growing body of research has demonstrated that informal learning environments can successfully increase students' knowledge and skills relating to STEM (Chubin et al., 2005; Eshach, 2007; Denson, Austin et al., 2015; Denson, Lammi et al., 2015). Informal STEM programs such as those that occur after school or during the summer have potential to improve interest in STEM, alongside soft skills and literacies that are important for navigating life in the 21st century. In contrast to the procedural constraints of formal educational settings, informal learning programs are flexible, can be built around fun and engaging activities, and can be structured to encourage team-based and collaborative work (Denson, Austin et al., 2015; Denson, Lammi et al., 2015). Informal STEM programs can also expose students to professionals from underrepresented groups who are working in STEM fields (Denson, Austin et al., 2015; Denson, Lammi et al., 2015). This exposure can help dispel stereotypes about who can be a STEM professional, thereby encouraging students to envision themselves in these fields. This formation of a STEM-career related self-concept can contribute to students' motivation and self-efficacy in pursuing these career paths (Mills, 2014).

Both individually and collectively, such features of informal learning environments can increase STEM interest among youth, eventually contributing to their intentions to further pursue STEM in their education and as a career path (Nugent et al., 2015). However, there remains much to be learned about why and how informal learning environments have successfully cultivated young, diverse talent in STEM, and what lessons from them can be incorporated into more formal educational settings.

This paper uses the case study of the Hexacago Health Academy (HHA) to explore how informal STEM learning environments produce emergent gains in critical thinking and problem-solving skills that are central to STEM fields. HHA is an informal STEM learning environment—specifically, a summer program—that focuses on issues of public health, using a curriculum of critical game design. The program introduces a novel conjunction of two dimensions to the exploration of informal STEM environments: the area of sexual and reproductive health, and the method of critical gameplay and game design.

First, this program turned specifically to sexual and reproductive health (SRH). STEM interventions in informal learning environments are poised to have particularly positive impacts within the realm of SRH. Many young people are eager for but lack information about SRH. The sex education requirements in public schools in many states are quite inconsistent. For example, as of December 2017, only 24 states and the District of Columbia require public schools to teach sex education. Furthermore, of those, only 13 states require these curricula to be medically accurate, and only eight mandate that instruction must be appropriate for a student's cultural background and not be biased against any race, sex or ethnicity (Guttmacher Institute, 2016). Instead of relying on information learned in schools, youth more often turn to online sources. Studies have suggested, however, that even as more than half of seventh through twelfth graders access health information online, much of the data available on these sites is inaccurate (Buhi, et al., 2010; Rideout et al., 2010; Holstrom, 2015). Since interest in SRH is already extant, and current information sources can be spotty at best, SRH represents a promising entrance point, in which the sharing of helpful health information can coincide with exposing adolescents to such STEM-related topics such as biomedical research and public health. The provision of informal learning environments geared toward SRH, then, provides an especially attractive option.

Second, along with its curricular commitment to SRH, HHA is also wedded to critical gameplay and game design as its core methodology. Emerging in the 1970s under the banner of "serious games," educational games have, over the past several decades, grown in stature as an attractive means of promoting self-motivated learning among youth. Educational games can both teach content and model real-world systems and processes, using a cluster of rhetorical strategies known as "procedural rhetoric" (Bogost, 2007).

HHA follows up on a longstanding tradition of using game-based interventions for youth health education, while adding a layer of participatory design (Maclachlan et al., 1997; Beale et al., 2007; Bochennek et al., 2007; van der Stege et al., 2010; Miller et al., 2013; Datta, et al., 2015; Enah, et al., 2015; Hieftje and Fiellin, 2015; Kayali, et al., 2015; Pendergrass, et al., 2016; van der Stege, et al., 2016; Cates et al., 2017). Games are a familiar and attractive cultural medium to youth in the U.S., especially in their digital form—72% of teenagers play video games online or on their phones, a number that is somewhat higher (83%) among Black teenagers (Lenhart et al., 2008). Even so, there is a persisting participation gap seen in youths' access and use of technology, which can lead to divergent rates of new media literacy (Hargittai and Walejko, 2008; Schradie, 2011; Torres-Albero, et al., 2014). Responding to this gap, HHA focuses on the design and critical play of analog games (i.e., board and card games) rather than digital games. This circumvents the need for widespread technology access among its youth participants, while at the same time promoting the unique forms of procedural literacy that games—both digital and analog—can provide.

Through a game-based curriculum designed to educate youth in issues of public health, HHA expounds on the creative, collaborative learning activities that characterize informal STEM learning programs. At the same time, the

intervention demonstrates the potential of informal STEM programs to successfully enrich and encourage underrepresented students' understanding and interest in STEM fields through engaging programming and exposure to minority and women STEM professionals. An evaluation of HHA suggests that informal STEM learning environments that draw from innovative educational techniques and interdisciplinary content offer compelling gains for underrepresented youth.

METHODS

Program Overview. HHA is a science and health education intervention using game design to invite participants to think about health systems as they operate at individual, interpersonal, community, and policy levels. The program leverages a variety of both traditional and innovative learning models to expose participants to a range of public health topics, research methods, and STEM careers. The youth-facing part of the program ran from 2015 until 2017, and was administered by staff and fellows from the Game Changer Chicago Design Lab a university-based game design and research lab, who supervised facilitators and delivered workshops. Workshops were on game design and Youth-Initiated Mentoring, a program in which young people learn to identify and cultivate mentoring. In this paper, we examine the summer 2015 program on SRH.

Participants attended weekly presentations by STEM and health professionals, during which they learned about current research in the health sciences, including U.S. health disparities, sexually transmitted infections and pregnancy, mobile health services, cancer epidemiology, fertility issues, gender and sexuality, sexual violence, health policy, and STEM education. These presentations gave youth the opportunity to network with professionals in the field, to broaden their understanding of health research and of health researchers, and to learn information directly from practitioners. These health professionals represented a diverse group, including a number of minority and women who are professionals in the field.

These traditional lectures and small group discussions provided the groundwork for the more experimental elements of the program. Youth synthesized information from the workshops, undertook additional research, and used the information they gleaned to design serious games about health for their peers to play. To learn the basics of game design, participants played and analyzed board games and attended workshops about critical gameplay and game design led by university staff and faculty. Later, in small groups of 5-6 youth each, they collaboratively designed their own board games based on a health topic of their choice, inspired by the presentations they attended. Each group was led by a facilitator who was either an undergraduate student or recent graduate of the University.

The collaborative capstone exercises yielded four completed board game prototypes, all of which addressed health topics. The first prototype, "Chicago Clinics" was a Trivial Pursuit-style game about the diagnosis and treatment of sexually transmitted infections, including unplanned pregnancy, sexually transmitted infections, childhood obesity, and achievement of educational goals. The second, "I Didn't Do It," was a storytelling game that embedded conversations about unplanned pregnancy within the everyday life choices of characters. The third, "Moving Too Fast," also addressed unplanned pregnancy, but used the genre of a resource management to require players to balance among extracurricular activities, social events, jobs, schoolwork, and sexual activity. Fourth and finally, "UFObesity" used a science fiction premise to defamiliarize and address childhood obesity. Throughout the program, youth playtested these games and participated in an iterative design process in which they gradually revised their games.

Overall, following the model of informal STEM learning environments, HHA connected students with health professionals, including minority and women professionals who may have inspired youth to challenge their conceptions of who could pursue a career in their field. Furthermore, HHA's game-based curriculum gave students an opportunity to process and apply the content-based knowledge in a design context.

HHA overview. The goal of year one of this five year program was for youth to create a game on the Hexacago Game Board that addressed a sexual and reproductive health topic. The three week summer program balanced group work, game play and design, science and health professional interaction and youth initiated mentoring workshops. Week one's structure included an introduction to board games, health topics and teams. Participants were immersed in team-building activities, board game mechanics and understanding rulesets. Week two focused on game development, and participants learned the landscape of game design as they worked in teams to create a game representing a topic they wanted to address. Week three highlighted how game play was a powerful, educational tool as participants showcased the games created, allowing students to express how they problem solved and thought about particular or challenging topics. The end products featured games on teen pregnancy, STI prevention, and obesity.

Over three weeks, HHA covered topics in pregnancy, STI prevention, contraception, epidemiology, abortion, gender and sexuality, sexual violence, HIV, fertility and population studies, health policy, health disparities, pediatric health, biostatistics, cancer, and mobile health. Participants interacted with over 15 university health and science professionals who presented on these topics and spoke about their professions and educations. In addition to having youth learn

how to create a robust game relevant to the real world, HHA fostered a rich mentoring environment, promoting higher education and future careers and building relationships with non-parental adults from their community.

Game play. Every morning of the program was dedicated to game play. These open board game sessions were intended to have participants to critically think about game mechanics, rulesets and procedural rhetoric. Games played included Clue, Settlers of Catan, Scotland Yard, Once Upon a Time, Saboteur, The Resistance, and Uno. After playing a game, teammates discussed why they liked or did not like the game, and in some cases, how the games connected to real-life behaviors and/or systemic structures.

Youth initiated mentoring. Afternoons were devoted to Youth Initiated Mentoring (YIM) workshops and game design workshops. YIM workshops focused on teaching youth to proactively nominate their own mentors, unlike traditional mentoring programs where youth are assigned to adult mentors. Within these YIM sessions, youth were encouraged to seek out, build and maintain relationships with non-parental adults from their community (e.g., teachers, professionals, extended family), as allowing youth to choose their own mentors has been shown to create longer-lasting, more beneficial bonds than merely assigning them (Schwartz et al., 2013). In addition to the workshops, youth were able to practice skills learned at a capstone YIM networking event.

Game design. Participants were split into four teams and worked together to design a game about a health topic of the team's choosing. Youth balanced subject matter with game play, and explored rulesets and board design techniques. Youth studied how to tell a compelling story with a character and practiced writing their game narratives. They would experiment with reconstructing classic games such as Tic Tac Toe, adding new aspects to it to see if the game still played well. Youth also participated in peer review of each others' games. This allowed them to critique and problem solve any issues with the game as it was being created, and also fostered constructive criticism and teamwork. In the finished product, every game created by the participants gave a socio-ecological perspective to issues of health and wellness, as youth analyzed larger structural and social factors. Each game represented a sexual and reproductive health issue that was relevant to youth, and whether or not it was playable at the end of three weeks was not a primary goal of the game design session.

Science and health professional interaction. A critical part of the summer program was showing students a glimpse of future career opportunities by interacting with professionals in science and health careers. University staff and faculty were recruited from a variety of different fields and occupations to increase interest in a wide range of STEM and health-related careers. Youth split from their teams for one hour each week to attend a small group interaction with a professional whose field they were interested in learning more about. Many of these small group interactions influenced what youth picked for a game health topic, and in addition professionals were able to provide opportunities for youth to ask career- or college-related questions.

University campus and laboratory tours. An informational session on ways to academically prepare for college admission processes was also included in the program, as was a campus tour. This campus tour provided youth an opportunity to ask questions, view college facilities, and learn more about courses offered. Youth also participated in a walking tour of a basic science research laboratory. This lab focuses on the investigation of new therapies for the treatment of ovarian cancer.

Game showcase. The last day of the summer program featured the game showcase, a chance for parents, friends, project staff and University faculty to gather as each team presented their project: a board game addressing a sexual and reproductive health issue. It served as an opportunity for youth to present the game they worked hard on for the past three weeks, as well as give others a chance to play it. Youth also were able to reflect on the game design process, and to discuss how games can serve as a learning opportunities.

Participant Recruitment. Participants were recruited through the Chicago GEAR UP Alliance, a grant program sponsored by the Department of Education. The Chicago GEAR UP Alliance is partnered with Northeastern Illinois University and Chicago Public Schools to increase the rate of high school graduation and promote college readiness. Eligible participants were high school students affiliated with a Chicago GEAR UP school willing to commit to program activities.

Data Collection. Demographic variables were assessed at baseline. Qualitative data were assessed following the three-week program. Participants were asked to assess HHA including best parts, interesting, hard, challenging, things to enhance or diminish. They were asked to assess working with a facilitator and working with peers using game-based methods. Regarding Stem and HHA, they were asked about their awareness of STEM in general and awareness of STEM within HHA. They were asked to assess whether and what about HHA might have increased their knowledge or interest in and excitement about STEM. Confidence and self-efficacy in learning STEM was assessed by asking if they "got" the STEM-related activities in HHA, whether their knowledge had increased and their ability to learn STEM had increased. Students were asked whether any STEM disciplines fit with their ideas about a future college major, career, or high school activity and whether that changed after HHA. To assess 21st century skills. Participants were asked about HHA's influence on curiosity and asking new or different

types of questions. They were asked about taking responsibility for their learning, managing their learning, and the way they approach teamwork. Finally, they were given an opportunity to make any comments they would like about HHA.

Data Analysis. All qualitative interviews were audio recorded and transcribed verbatim. A coding scheme was created based on the qualitative questions. The coding scheme was expanded upon as new themes arose from reading the transcripts. Atlas.ti software was used to code the transcripts by two independent coders who used discussion to reconcile disagreements in coding decisions. A matrix was used to organize and categorize quotations. Salient thematic areas were identified. Representative quotations are used to describe the major themes.

RESULTS

A total of 24 youth were recruited for the study. The majority of participants was aged 16, and all participants self-identified as either Non-Hispanic Black (79.2%) or Hispanic White (20.8%). There were slightly more female participants (58.3%) than males (41.7%) enrolled in the program.

Qualitative Findings. Focus group conversations revealed a positive assessment of HHA and game-based learning with endorsement of exposure to STEM and health professionals for learning. Four major themes relating to 21st century skills emerged, including the development of critical thinking skills through game-based health education that translated factual knowledge into a complex system of gameplay; the program's contribution to collaboration, teamwork, and mentorship that are key to STEM and health fields; the program's contribution to knowledge of both health topics and game design; and finally the encouragement of positive risk-taking in educational activities. Representative and anonymized quotations are used to illustrate these themes.

Regarding the challenges of HHA, young people were challenged by taking all that they learned and collaboratively developing a game. In the words of one young person:

"Probably the most difficult was coming up with the idea for the game 'cause we knew the topic but we didn't really know where to start. A lot of people think you're going to start with the board or you're gonna start with the cards or money, but really the topic and being able to bring in the ideas towards research is where you're supposed to start, and then little by little, slowly the ideas start coming in". - P9

All students rated the program highly. Positive factors included learning games, staying motivated throughout, working in teams, having speakers come, getting to work with one another. Some described being reluctant to come, or not wanting to learn about sexual and reproductive health, or not being the type to participate in programs. Nevertheless, these students were surprised and encouraged and wanted to participate in future programs.

Regarding things to change, students mentioned a number of things to enhance. One participant wanted more freedom stating that the facilitators watched over them making them feel like they were in elementary school rather than young adults. Youth wanted more access to computers, more professionals, and a wider array of professionals. A few mentioned the program's early morning.

Participants appreciated being made aware of professionals but also the tips and advice they gave. One said they learned. "Never give up, anything is possible as long as I just stay with it and just keep trying, keep doing." Another said, "they gave me a few tips about how to keep your focus… have a good education to get there, go to college. Basically get your good education so you can be successful."

Finally, students described some of their favorite topics including: HIV, how different contraceptives are made, physiology of the ovaries, science of gender, and neuroscience. They also enjoyed visiting the university and seeing laboratories and the college campus.

Game-based health education developed critical thinking skills by translating factual content knowledge into a more complex and designed system. The game-based curriculum enabled youth to develop skills in critical thinking and inquiry that are vital components of literacy in the 21st century, and that can be operationalized in both health and STEM fields. While classroom education often focuses on content knowledge, the work undertaken in STEM fields, both at universities and in the workplace, is necessarily more nuanced. The capstone component of HHA gave participants an objective—creating a game—that required research, information synthesis, and hands-on application in the construction of a formal system that would have to communicate health concepts to players. Some students felt their group had strong ideas, but were unsure how they would follow through in creating a playable game around their compelling theme. When asked about the challenges with respect to HHA, one participant reported:

"*Creating our game. Creating our game was so difficult. We knew we wanted to do our game about teen pregnancy, but we didn't know exactly how we were going to accumulate it all into a game. We didn't know how it was going to be, so that was the most difficult part, but we made it through…" – P1*

Even with a promising idea, translating that theme into a gameplay experience—complete with a game board and game pieces—proved challenging. A student explained:

"Probably the most difficult [part] was coming up with the idea for the game 'cause we knew the topic but we didn't really know where to start. A lot of people think you're going to start with the board or you're gonna start with the cards or money, but really the topic and being able to bring in the ideas towards research is where you're supposed to start, and then little by little, slowly the ideas start coming in." – P9

Although widely reported as a challenge of the program, participants seem to have embraced the difficulties of creating an educational game on a health topic. Furthermore, it was evident that participants developed a strong sense of pride of the work they accomplished, in spite of the challenges they faced. One student shared their initial trepidation when tasked with designing a game in three short weeks:

"... when it comes to designing a game, there are a lot of aspects that you have to look at, and me, myself, I don't think I would have been able to do it in three weeks. Maybe if I really put time and effort in it, but right now, I'm happy with the work that I did cuz I actually designed the board and I came up with one of the narratives, because it's going to be narrative stuff, so I came up with one of the narratives, and I'm pretty proud in what I did…I contributed." – P6

Despite the challenges, students were able to translate SRH information into a designed game system within the constraints of a three-week program.

Game-based curriculum encouraged the collaboration, teamwork, and mentorship that are vital to STEM and health research. A cornerstone of informal STEM learning environments is their flexible activities and assignments, which encourage teamwork and collaboration. HHA participants overwhelmingly pointed to game-based collaborative and team activities as the most impactful experiences of the program. Several youths reported that they consider themselves to be quiet students who prefer to work individually as opposed to in groups. One participant noted,

"...me, I'm not really big in group activities, and I'd rather just be on my own and, not do my own thing, but just do my own comfort zone, but I know that she [interviewee's facilitator] wanted me to get out my comfort zone…" – P6

Another participant also focused on the significance of stepping outside their comfort zone after an initial concern about working with new collaborators. When asked about the positive attributes of the program, this student observed:

"But for me it was mostly getting to know new people 'cause me and my friend we came here and we got separated in groups. And mostly when I do that I'm like, "Oh God, I don't know anybody" but as soon as I got in everybody was all nice and happy so it made me feel comfortable. For me it's like meeting new people and getting out of your comfort zone." – P20

While challenging for some students, the group work facilitated by HHA's game-based curriculum encouraged teamwork, even among reticent participants. One HHA participant highlighted the collaborative nature of their team's work in creating and playing games:

"We worked together as a team, we all helped do something, we all gave advice, we all gave examples and we all just put it all together and created our game." – P1

One HHA participant reported that a major challenge they face in the formal learning environment of their school is feeling unable to connect to their teachers (P20). A student's self-view can be influenced by developing mentoring relationships, which are critical in informal STEM learning, as well as the professional networking that these environments facilitate.

Mentorship and networking in the health sciences are also crucial components of knowledge acquisition. One HHA participant expressed appreciation for the networking opportunities with potential mentors that HHA presented:

"Y*eah, again when we went to go talk to the people, I mean, there was, they taught us to, at the end, we have to show appreciation, and we also have to show…if they have any internships or any job opportunities, we could give them our information, so obviously I gave out as many business cards that I could to be able to get something in the future. It's not really big connections, but it's something. I appreciate the way that they did that." – P6*

Game-based health education broadened participants' understandings both of the health sciences and of games. HHA's game-based curriculum modeled and encouraged youth to develop a deeper awareness and understanding of health as an interdisciplinary and broadly efficacious field. For several participants, the designation of HHA as a "health academy" influenced their initial expectations for the program. Participants reported that their expectations were aligned with traditional notions of health education, in particular those practiced in their schools. Delivering health education through gameplay and game design inspired participants to challenge their previous notions of the scope and boundaries of health education. One student explained:

"Being a part of it for the three weeks, I thought it was going to be, like in the name, it says health academy. We were going to be taught to eat less, like a regular health course. But, it was a lot more than what I had thought it would be. I thought it would be really boring, but it's a lot of fun. The facilitators make it really fun for you, and they make it so that it's not all based on adult things. They make it sound a lot more interesting for us teens" – P9

Another student shared:

"I wasn't expecting to like the program as much as I did because I wasn't really into sexual education, it didn't excite me but I'm actually glad I did the program; I actually liked it." – P5

Although they were challenged to revise their notions of the scope of health education, HHA participants demonstrated notable learning gains in their content knowledge. Several youth were quick to identify what they learned during their exit interviews. When asked about their attitudes towards learning about health as a result of the program, one student observed:

"When we have different professionals come to talk to us, I learned about different diseases and I learned that sexual harassment - I really didn't know you had to be the legal age for 17 to actually be old enough to have interactions with different people, so I have learned that, and that was really surprising to me." – P12

Another participant reported that they learned about a new form of contraception:

"There was a health topic that I didn't know about. It was a birth control thing that I never heard of. It was called plan B. I never heard of it until I got here." – P4

One youth shared what they learned about local law regarding abortions among minors, as well as newly acquired information about STI prevention:

"Well now that they changed the abortion rule, where if you get an abortion in Illinois, that they are, they still have to tell your parents that you're having the abortion. So before, it was just consent, and I also learned that condoms were, they are higher at protecting you from an STI instead of pregnancy. I always thought that condoms were more just for pregnancy, and then, yeah, I didn't really know about the STI. That was pretty interesting." – P6

Alongside expanding participants' notions of health education and health-related topics, HHA also challenged their conceptions of games as a genre of entertainment, and encouraged them to confront the complexities of serious games and game design. In their exit interviews, many participants latched on to the educational value of gameplay for instruction and for student learning. When asked about their attitude towards creating and playing games, one participant explained:

"I would say we should use it [games] because I learned so much from using board games and putting it as informational board games too, cause some people they're visual learners and they would know—since they're having fun, they're absorbing the knowledge too and they wouldn't know it cause I didn't know it at first and then I started answering questions that I wouldn't normally know. I would start to answer them right and I'm like "Oh, hey I know that question. I'm awesome!" – P15

Another student reported:

"I describe it [creating and playing games] as different. Kinda difficult, it was just– it had you thinking a lot. It wasn't like other games you – like long like Monopoly, Trouble, games like that. It was – I had to go over the game a few times before even playing it, kept on asking questions about the route, and it was a learning experience." – P21

One HHA participant alluded to the applicability of lessons learned through games beyond the board:

"I would recommend to use games for learning because in our games there's a lot. It's a story to me, and it can make a person double think about things they are going to do and it will help them in the outer world and in the long run." – P8

Innovative learning methods can encourage positive risk-taking in enrichment and educational activities. Many participants reported that they were surprised by numerous aspects of HHA: by the broad conception of health education, by the rigors of critical gameplay and game design, and by the learning gains that serious games, including those on health topics, can achieve. By embracing these surprises, participants reflected on their curiosity to pursue other interdisciplinary and innovative education programs, as well as on their confidence in approaching and appreciating learning challenges.

One student shared that their favorite activity was "making the games" and "making them challenging." When probed further by the interviewer, the youth shared that liked most, "New things, doing things I never did before." Another participant echoed similar sentiments:

"I think it was a great program because I had never done anything like this before. And that was another reason why I wanted to do it, because I had never went to a Game Changer program before. To actually sit down with a team and make a game, I never did that before. So it was something that I never did and now I experience more." – P1

Another youth reported a newfound interest in pursuing novel enrichment activities. When asked about the positive attributes of HHA, they reported:

"Well it encourages me to participate in more programs because again, I never really participated in any programs at all. I also know one of the students here because we're friends and we go to the same school, and she was going to sign up and then I was just going to sign up but yeah, I think I will pursue further going to different programs now because this one I kind of like and I enjoyed it so much so I might just go on and sign up for other stuff." – P7

Another theme that emerged was the central role of risk, feedback, and constructive criticism, which proved to be essential components of the game design process. The task of creating games that were simultaneously informative and fun required a process of rapid prototyping, regular feedback, and iteration, something that participants may not have been exposed to in formal learning environments. One participant recalled the playtesting phase of their game design project:

"...we had to go to other tables and play their games. People gave us feedback, and we had to come together and figure out how we can make it easy and difficult at the same time and have fun with the game too." – P19

DISCUSSION

This study describes a summer program, which focused on issues of STEM and health, using a curriculum of critical game design. The design of the HHA summer program was based upon the principles of informal learning environments, particularly the strength of such environments to expose students from groups underrepresented in STEM fields to professionals of their same gender or ethnic background. In addition to being non-traditional and informal in its summer-camp structure, HHA further diverged from typical formal learning environments in being based around the participatory design of critical, educational games. Overall, study participants seemed highly receptive to the format of HHA. All themes qualitatively explored speak to the unique strengths of game-based health education, especially as it stands in contrast to formal educational environments. Furthermore, participant responses reveal a number of ways in which game-based informal learning environments such as HHA are particularly suited to foster STEM interest and advancement among youth.

Research on informal STEM learning environments has suggested that, especially among underrepresented and under-resourced youth, learning gains can extend beyond the acquisition of content knowledge, and perhaps the most compelling outcomes are in how these students come to view new opportunities for themselves as future professionals (Denson, Lammi et al., 2015; Mills, 2014). Taking advantage of the flexibility of informal learning environments, HHA was designed around the notion of self-perception as a learner. The program's focus on membership and networking was clearly appreciated, as evinced by participant responses. By design, the program explicitly ties STEM fields to health topics with everyday relevance to young people.

In addition to taking the form of an informal learning environment, HHA was also designed around participatory game design. In health education, a game-based curriculum productively destabilizes and enriches participants' conceptions of STEM and health-related fields by situating and motivating their learning in a fun, interactive environment. Research in informal STEM learning environments has suggested that one of the major advantages to these programs is that they empower youth to view learning as a fun activity, even when difficulty is encountered (Denson, Lammi et al., 2015). Furthermore, by untethering STEM content from traditional formal learning environments—where students often receive information through instruction, rather than active exploration and engagement—game-based health education empowers youth to apply knowledge beyond the classroom or the lab, and out into the real world.

The capstone game design exercises of the summer 2015 HHA session inspired coordination outside the traditional boundaries of academic group projects. In STEM fields, the lab model encourages collaboration and reinforces the development and discovery of knowledge through shared effort. Though more often associated with the arts, game design shares many parallels with STEM work. When creating a game, a designer, like a scientist, benefits from working in a team. As a result, game design can develop the skills that enable a student to be successful in STEM fields.

Playtesting, iteration, and prototyping are key components of the game design process. The process of digital game development takes several cues from existing models of software development, with their focus on a "fast loop" of rapid prototyping, and a lack of attachments to individual iterations of a project (Schell, 2008). Analog game development retains these core features, fostering a work environment in which critical feedback is necessary, and "failure" is cast as a crucial step in the iterative process, rather than a stumbling block to be avoided. This low punishment for risk encourages forms of risk-taking that are often structurally discouraged within formal learning environments. As illustrated in participant responses, this can inspire confidence when approaching learning challenges.

The "safeness" of failure within the iterative process of game design also extends to the play of games themselves. Losing, re-trying, and gradually learning to make better decisions is an essential part of the game-playing process. This fact that has not been lost on educators. Games privilege trial-and-error processes of problem-solving and learning: within the context of play, risks are balanced with rewards, and the emotional stakes of failing are lowered (Jenkins et al., 2006). This diverges starkly from how failure is typically treated in formal learning environments. In opposition to the severe consequences attached to failure within a classroom, proponents of the uses of games in education have held up games' mode of "safe failure" as a positive pedagogical model (Chess and Booth, 2014). The promotion of safe failure can be especially productive in STEM learning environments, as the trial-and-error learning encouraged by games mirrors the process of hypothesis-testing and gradual refinement of knowledge that forms the backbone of the sci-

entific method (Jenkins et al., 2006).

A number of research limitations must be noted. The sample size for our 2015 summer program is small, meaning that there are limits to the generalizations we can make about the behavior outcomes a program such as HHA might have within a larger sample of young people. Furthermore, the general format of the summer program was restrictive, in a way that some students pushed against. The program's focus on sexual and reproductive health meant that some students were unable to make a game focused on the particular topic that they wanted to make. As noted above, the youth-facing summer program portion of HHA continued during the summers of both 2016 and 2017, which alleviated some of these problems: not only do we now have a larger samples sizes, but participants in later summer programs were given increased leeway in the subject matter of their educational games (while remaining within the arena of public health issues).

The learning achieved by participants of HHA—most notably, a deeper awareness and appreciation of the interdisciplinary and wide-reaching complexities of both critical game studies and health-related fields—demonstrate the utility and promise of a game-based health education curriculum as an emerging learning design model. Coupled with the gains that have been noted in studies on informal STEM learning, game-based health education not only can transform the learning environment into one that is collaborative and fun, but a game-based curriculum also can encourage the development of skills that are vital in STEM fields and for 21st century literacy. Given the research that currently exists establishing a positive correlation between participation in informal learning environments and STEM interest and advancement among underrepresented youth, game-based health education presents an exciting opportunity to address and rectify the demographic and gender imbalance in STEM, stimulating interest and decreasing attrition rates among members of underrepresented groups.

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ABBREVIATIONS

HHA: Hexacago Health Academy; SRH: Sexual and reproductive health; STEM: Science, technology, engineering, math; PISA: Program for International Student Assessment; NAEP: National Assessment of Education Progress; U.S.: United States; STI: Sexually transmitted infection; HIV: Human Immunodeficiency Virus; GEAR UP: Gaining Early Awareness and Readiness for Undergraduate Programs

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