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MOONSHOT: REDESIGNING NASA'S HIGH SCHOOL AEROSPACE SCHOLARS EXPERIENCE AT JOHNSON SPACE CENTER FOR ONLINE DELIVERY

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Moonshot is the redesign of NASA's High School Aerospace Scholars (HAS), which traditionally engaged Texas high school juniors in a 16-week online course for credit and an intense week-long onsite experience working in teams with experts at NASA's Johnson Space Center (JSC). Due to the novel coronavirus (COVID-19), our challenge was to design, develop, and deliver an online virtual experience to replace the all-expenses-paid six-day residential summer experience at JSC where HAS participants traditionally work with like-minded peers and NASA experts on authentic design challenges.

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INTRODUCTION

Through the NASA STEM Pathway Activities—Consortium for Education (NSPACE) project, Oklahoma State University designs and delivers unique NASA experiential STEM engagement opportunities. The goals of NSPACE activities are to create unique opportunities for students to contribute to NASA's work in exploration and discovery; build a diverse future STEM workforce; and strengthen connections to NASA's mission and work.

NSPACE's High School Aerospace Scholars (HAS) activity, now in its 22nd year, is also supported by the State of Texas, Houston Livestock Show and Rodeo, Texas A&M Engineering Experiment Station, and Rotary National Award for Space Achievement. HAS begins each November with a 16-week online course for Texas high school juniors. The course covers NASA activities related to space exploration, Earth science, technology, mathematics, and aeronautics, and students complete design challenges and attend monthly webinars with NASA scientists and engineers who have a direct impact on NASA's space program. The 16-week course is approved for one-half of an elective high school science credit in Texas and is aligned to the Texas Essential Knowledge and Skills (TEKS) standards for Scientific Research and Design (Texas Education Agency [TEA], 2018) and the Next Generation Science Standards (NGSS) (NGSS Lead States, 2013). About 1,000 students enroll in the HAS online course each year.

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Of the 1,000 students who enroll, approximately 270 students who successfully complete the 16-week online course are invited to an all-expenses-paid, six-day residential summer experience at NASA's Johnson Space Center (JSC) in Houston, Texas, where they work in teams and with NASA experts to design an authentic mission and complete hands-on engineering design challenges. The onsite experience, which is also aligned to the TEKS and NGSS, is approved for an additional one-half of an elective high school science credit, making onsite attendees eligible for one elective high school science credit in Texas. Due to the novel coronavirus (COVID-19) pandemic in Spring 2020, the NSPACE team was challenged to radically redesign the highly successful onsite HAS experience into an engaging, effective online learning experience.

TRADITIONAL DESIGN

The activities for the six-day onsite experience are designed for students to engage in activities in the same manner and work environment as NASA employees. The activities are organized into four themes: team building, preliminary design review (PDR) builds, design challenges, and PDR presentations.

Team Building

Students are organized into teams, and each team is given a specific challenge to contribute to the overall mission. Each student within a team takes on a role with specified responsibilities. For example, the Systems Engineer communicates with the Systems Engineers on other teams and coordinates the work of other team members (e.g., Integration Manager, Design Manager, Technicians) on their own team to complete their work within the given time frame.

PDR Builds

Each team works together to research information on mission-specific topics, select subtopics to study more in-depth, and build a prototype through a design challenge on one of the assigned mission stages.

Design Challenges

Each team builds a 3D model of either an autonomous cargo lander or an exploration rover, which must include designated features. Teams use the themes of overall science goals, precision landing, cargo and payloads, and in-situ resource utilization experiments to guide their design.

PDR Presentations

Each team delivers a presentation describing how their preliminary design meets all system requirements with acceptable risk and establishes the basis for proceeding with a more detailed design.

PROPOSED REDESIGN

When the COVID-19 pandemic hit and made an onsite experience at JSC for over 250 high school students unrealistic, the NSPACE team devised contingency plans and presented four different HAS delivery plans to JSC's Office of STEM Engagement administrators in April 2020. Two plans featured onsite experiences for 180-270 students at JSC, one a hybrid delivery with 270 students travelling to JSC for a short onsite experience, and one virtual gamified experience for 656 students. The virtual plan was selected and approved by the JSC Director since at that time it was uncertain whether JSC would be open to visitors in July 2020.

The plan proposed creating a gamified, virtual onsite for the Artemis mission. NASA's Artemis program focuses on landing the first woman and next man on the Moon by 2024. The plan consisted of three levels (team building, PDR build, and PDR presentation) and optional design challenges that could earn teams bonus points (see Figure 1, next page). The challenge was to replace a highly popular and effective onsite experience where students could interact with NASA personnel at JSC with a second online experience.

The Design Team

The first step was to assemble a full design team to meet all anticipated needs. The NSPACE team contributing to HAS consisted of the NSPACE Principal Investigator (PI), an assistant director focused on logistics, an assistant director handling purchasing and personnel, the lead education coordinator over all NSPACE activities, the STEM collaborations lead coordinator, three HAS education specialists, an IT specialist, an external evaluator, the NSPACE activity coordinator, and a graphic designer. Two university faculty members with expertise in learning, design, and technology and STEM education joined the existing NSPACE team as the instructional designer and STEM content specialist to complete the Moonshot design team.

Most of the design team was stationed at JSC in Houston, Texas, three at Oklahoma State University in Stillwater, Oklahoma, and one in Colorado; however, due to the COVID-19 pandemic, all were working from home and collaborating from a distance. Throughout the paper, the pronouns *we* and *our* will be used to describe the entire design team, team member roles will be used to describe individual efforts, and specific subgroups of the team will be explained.

Collaboration Strategy

Once the full team was assembled, we set up a virtual planning space in Microsoft Teams using a OneNote notebook, regular Microsoft Teams meetings, and a virtual design space on the learning management system (LMS), Canvas. While the full design team contributed to the OneNote notebook

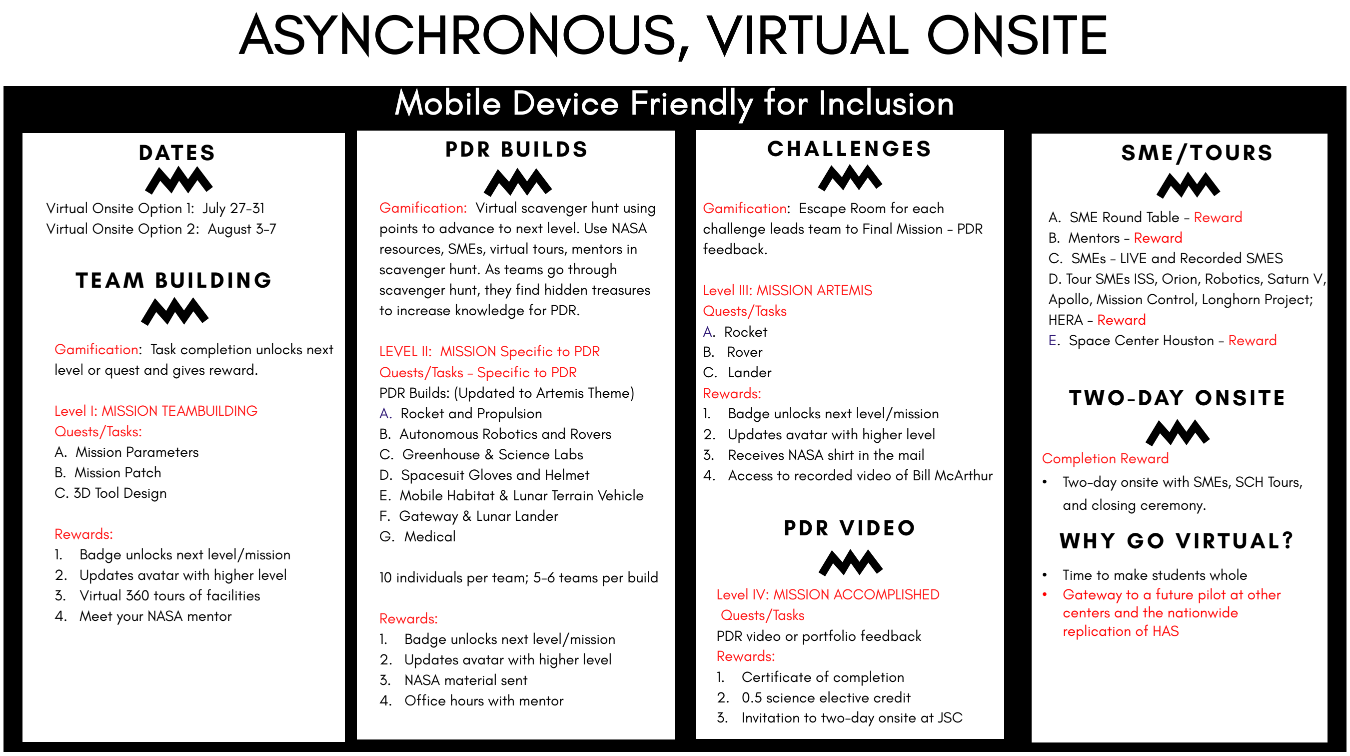

FIGURE 1. Proposed components of the virtual gamified experience chosen to replace the traditional onsite at JSC.

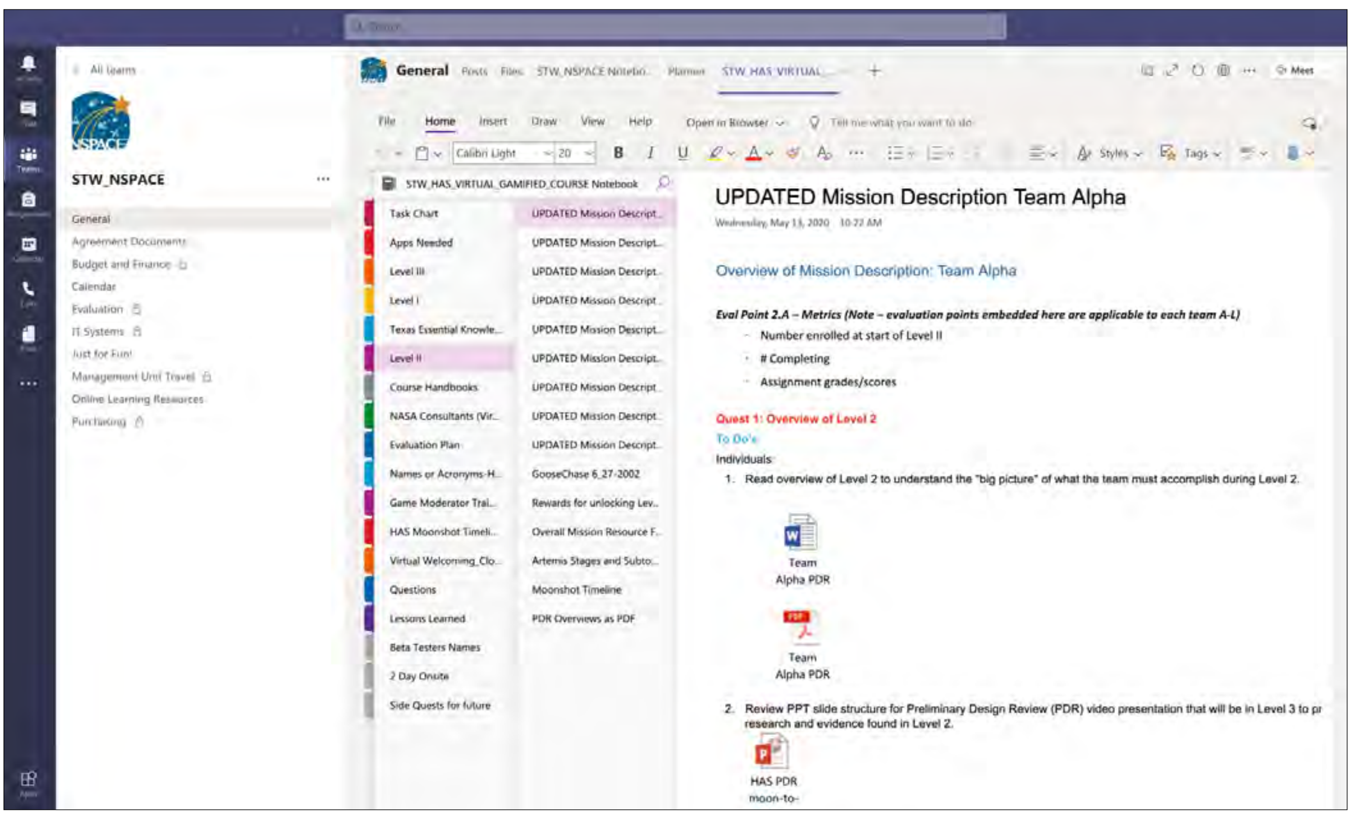

FIGURE 2. Our virtual planning space in Microsoft Teams and OneNote.

and met regularly, specific subgroups of the design team met daily, bi-weekly, and/or weekly from May to August to make design and development decisions.

Virtual Planning Space

Our Microsoft Teams planning space was populated with a General channel that embedded our OneNote notebook. The notebook was organized into sections for a task chart, apps, game levels, the evaluation plan, content standards, course handbooks, NASA consultants and game moderator training, a timeline, names/acronyms reference, questions, welcoming/closing ceremonies, and lessons learned for future iterations (see Figure 2). Existing channels for Budget and Finance, Evaluation, and IT Systems were used to store key files and hold chat conversations.

Regular Design Team Meetings

Virtual meetings were held through Microsoft Teams, so access to shared files, chat, and collaborative notetaking was all available in one tool. The main design team, which was composed of the NSPACE PI, NSPACE lead education coordinator, STEM collaborations lead coordinator, external evaluator, instructional designer, and STEM content specialist, met weekly for the first month, changing to bi-weekly at the end of June. The IT specialist and graphic designer were added to the main design team meetings in June. Examples of topics addressed in these meetings include gamification strategies; design of course graphics; course content aligned with standards; third-party software acquisition, installation, and integration into Canvas; beta testing procedures; formative and summative assessment; and evaluation.

The STEM collaborations lead coordinator met daily with the three HAS educational specialists who designed and developed course content; collectively, these four design team members make up NSPACE's HAS staff. During these meetings, the HAS educational specialists shared updates, discussed problems they were having, and were assigned new tasks.

The NSPACE lead education coordinator, STEM collaborations lead coordinator, and the graphic designer met bi-weekly to develop the images representing the levels and quests in the Moonshot course. Purposely, this illustrations development subgroup used NASA images to give a realistic feeling to the gamified course.

An evaluation subgroup that included the NSPACE PI, NSPACE lead education coordinator, STEM collaborations lead education coordinator, and external evaluator met weekly to ensure evaluation questions were embedded into each level. Questions developed required students to reflect upon the mission-planning experience, STEM identity, content knowledge, and course design.

Virtual Design Space

Once the educational specialists shared their developed instructional materials in OneNote, our instructional designer vetted them for clarity and language before developing them as assignments in Canvas. We discussed the look and feel of each assignment during regular meetings of the main design team. When the illustrations development subgroup finalized and approved the graphics, which were designed using NASA-approved style guidelines for font and appearance, our instructional designer presented several options for navigating the course using html image maps. Eventually, our beta testers and game moderators tested the course created in our virtual design space, and we imported a revised version of it into each section for our student implementation.

VIRTUAL ONSITE CONCEPTUALIZATION

Each of the design team members contributed to the conceptualization of a virtual experience that would afford all 656 completers of the 16-week online course (rather than a select group of completers) the opportunity to participate in an authentic mission and complete hands-on engineering design challenges without travelling to JSC.

"How Gamified Do You Want It to Be?"

Our first main design team meeting shaped the overall vision for the virtual gamified experience we designed. At the beginning of the meeting, the NSPACE PI, NSPACE lead education coordinator, and STEM collaborations lead presented the delivery method approved by the JSC Director to the rest of the main design team. Additionally, they stressed the importance of making the virtual onsite experience distinctly different than the 16-week online course completed by HAS students; after all, students were missing out on an opportunity to attend an all-expenses-paid, six-day experience at a NASA space center, interact with peers from around the state who had similar interests, and engage in formal and informal conversations with members of the NASA workforce. The virtual onsite experience needed to be a worthy alternative that engaged students in similar ways.

In response to this presentation, our team's instructional designer asked, "Well, how gamified do you want [the virtual onsite course] to be?" A few moments of silence passed, and as if everyone's peripheral glances within the Microsoft Teams meeting secured eye contact and a clear response, the STEM collaborations lead coordinator replied, "As gamified and interactive as you can make it—what did you have in mind?"

Before discussing the design constraints that extended beyond the LMS (see Design Constraints, below), our instructional designer proffered a concept that she likened to worlds in Super Mario World for Super Nintendo (Nintendo, 1990). Like Super Mario World, students would navigate a "world" by completing quests on a map of the world, and students could access "bonus areas" by completing side quest challenges. Unlike Super Mario World, students could only complete each world in a sequential manner; they would not have the opportunity to warp to another world—therefore skipping one or more before it—because of the learning objectives and systems engineering that needed to be incorporated into the virtual onsite experience.

Although nothing official was decided at the end of this meeting, the idea of creating maps for each level (aka world) of the experience resonated with the NSPACE lead education coordinator and STEM collaborations lead coordinator as they began to envision what was possible with a virtual on-site experience. They began discussing the concept with our graphic designer and decided that they wanted to proceed with the concept as long as it was gamified, clearly distinct from the 16-week online course, and accommodated the additional design constraints.

Design Constraints

As noted by Jonassen (2008), "Virtually all forms of analysis in instructional design are aimed at identifying and accommodating to various constraints." The design of Moonshot was no different, and while each constraint influenced the design decisions we made, none hindered the concept of the course we sought to design and develop.

The first constraint was the need to use a specific LMS: Canvas. Not only did NSPACE use Canvas for its online STEM engagement experiences, but also all students would be familiar with the platform, making it a seamless transition to this online experience. That said, our second constraint was the need to distinguish the Moonshot virtual onsite experience from the 16-week online course that serves as the first part of the full HAS activity. Students knew if they successfully completed the 16-week online course, it would make them eligible to be selected to attend a six-day onsite experience at JSC, which was part two of the full HAS activity. When the COVID-19 pandemic shut down JSC to visitors, many students were disappointed, which required us to develop an engaging experience where students felt connected with one another—much like they would if they were onsite.

Our third constraint consisted of using approved tools to design and develop the course. NASA's list of approved tools limited what applications could be used to collaborate on the design and development of the course as well as the applications that could be integrated into the course. As we began collaborating as a design team within those constraints (i.e., Microsoft Teams), it became clear that we needed to include external tools to distinguish Moonshot from the other HAS online course (see Design Decisions, below). After surveying students to assess the technology they would have available to complete the course, we learned that each student had access to both a computer (desktop or laptop) and a mobile device. We evaluated a number of tools to help us achieve our goals; however, a subgroup of the design team composed of the NSPACE PI, assistant director focused on logistics, assistant director of handling purchasing and personnel, and IT specialist met with vendors, discussed each tool, conducted additional evaluation, and made decisions about each tool's approval.

Since HAS is a NASA activity run through a cooperative agreement with a university, all federal government IT security requirements as well as university institutional review board policies for working with minors factored into decisions regarding apps to use and which features of those apps could be used. Unlike using an LMS with a school district or university, students enrolled in NSPACE online courses are not issued a domain-specific email address; students are enrolled with login ids that are connected to a student-provided personal email account. Because of this constraint, our use of external tools had to be strategic, easily accessible by students, and not connected to a specific suite of tools. Additionally, for evaluation purposes, we sought to integrate tools in such a way that student performance data and all survey responses collected from a variety of apps would be tied to each student's individual login id.

DESIGN DECISIONS

The redesign of the HAS onsite experience was guided by seven of Bonk and Dennen's (2005) principles for creating massive multiplayer online games: Achievement, Distributed, Multiple Routes, Practice, Probing, "Regime of Competence," and Self-knowledge. In addition to these gaming principles, the redesign drew on Kopcha et al.'s (2016) five elements of a gamified course design—levelling up, badges and awards, mastery-focused, quests, and a boss level—to organize the experience, embed each of the gaming principles, and reinforce the gaming environment. Each design decision was supported by one of the seven gaming principles, aligned with one or more gaming elements, and leveraged specific external tools for evaluation purposes (see Table 1). For example, the Achievement principle recognizes learner rewards for mastery; elements associated with rewards for mastery align with levelling up, badges and awards, mastery-focused, and quests. During our design decision process, we determined a badging app would be most appropriate to align with this principle and element. Badgr was selected for its available learning tools interoperability (LTI) for integration into Canvas, flexibility in importing original graphics, and ease of use. Similar alignment efforts are presented in Table 1.

The gamified onsite experience was designed in Canvas, which is the same LMS that all HAS students experienced

GAMING PRINCIPLE	DESIGN DECISION	GAMIFIED ELEMENT	EXTERNAL TOOLS
Achievement *Learners are rewarded at each level for mastering knowledge and skills.*	Learners receive badges and unlock rewards after the successful completion of each quest and each level.	• Levelling Up • Badges & Awards • Mastery-focused • Quests	• Badgr
Distributed *Learners grow by interacting with other learners, technology, and tools.*	Learners work in teams to complete PDR builds. All teams work together to successfully complete the mission. The online environment engages learners with a variety of technological tools.	• Quests • Boss Level	• GooseChase • Padlet • Pronto
Multiple Routes *Learners can progress and in more than one way, which encourages them to be decision makers and problem solvers.*	Teams of learners have a choice about the focus of their team's mission and build. Within the quests, individual learners make decisions about how and what to contribute to the mission.	• Levelling Up • Quests • Boss Level	• GooseChase • Padlet • Pronto • Qualtrics
Practice *Learners spend time practicing in a compelling context.*	Learners practice and apply content learned individually and as a team using a variety of tools.	• Levelling Up • Quests	• GooseChase • Padlet • Pronto
Probing *Learners are encouraged to engage in cycles of inquiry.*	Learners engage in guided inquiry that leads to decisions they make about their team's mission and how the alignment of all teams' decisions will result in a successful mission to the moon.	• Levelling Up • Mastery-focused • Quests	• Padlet • Pronto
"Regime of Competence" *Learners are challenged to push beyond their comfort and/or current ability zone (in an attainable and safe way).*	Learners are pushed to apply systems engineering, science, technology, and math concepts individually, in small groups, and as a large group by leveraging a variety of tools.	• Levelling Up • Quests • Master-focused • Boss Level	• Flipgrid • GooseChase • Padlet • Pronto • Qualtrics
Self-knowledge *Learners learn about the learning environment and themselves through the gamified experience.*	Learners reflect on their learning and how the experience connects to their STEM identity.	• Levelling Up • Badges & Awards • Mastery-focused • Quests • Boss Level	• Badgr • Flipgrid • GooseChase • Padlet • Pronto • Qualtrics

TABLE 1. Alignment of the design decisions with the gaming principles, gamified elements, and external tools for evaluation.

during the 16-week online course. Although students had previous experience with Canvas, this was the first time they participated in a gamified learning environment with the HAS activity. Because the vocabulary used in gamified learning environments is an important component that can contribute to learners' engagement (Deterding et al., 2011; Stansberry & Haselwood, 2017), we intentionally used "quests" in lieu of "assignments" and "levels" in lieu of "modules" for the purpose of transforming the traditional Canvas environment students were accustomed to into a unique and memorable environment (see Figures 2-4)—much like the experience they would traditionally have at JSC.

Six external tools were carefully selected to integrate with course content to support the gamified elements and overall course evaluation: Badgr, Flipgrid, GooseChase, Padlet, Pronto, and Qualtrics (see Table 2). Badgr adds gamified elements to online courses through badges and leaderboards; the tool creates an alias name for students to protect their privacy while showing each individual's progression in the course on the leaderboard. Badgr allowed badges to be awarded after the completion of each quest. Flipgrid is a video discussion tool. Students were required to use this tool to introduce themselves to their peers and game moderators in Level I. GooseChase is a mobile application that allows participants to complete virtual scavenger hunts. GooseChase missions require a variety of submission types, such as 300 characters of text, photos, or 15-second videos. Students were required to complete an individual and a team scavenger hunt during Level 2. Padlet is a discussion board platform for virtual brainstorming, organization, and documentation using text, images, videos, links, and files. Students used Padlet in all three levels for team activities and PDR research documentation. Qualtrics is an online survey platform. Students were required to submit consent forms, formative assessments, and reflections using this platform during each level.Pronto is a group video and text chat tool that allows users to text, video chat, livestream, file share,

EXTERNAL TOOL	DESCRIPTION & PURPOSE	QUESTS		
		LEVEL I	LEVEL II	LEVEL III
Badgr	Badgr adds gamified elements to online courses through badges and leaderboards; the tool creates an alias name for students to protect their privacy while showing each individual's progression in the course on the leaderboard. Badgr allowed badges to be awarded after the completion of each quest.	1, 2, 3, 4, 5, 6	1, 2, 3, 4, 5, 6, 7, 8	1, 2, 3, 4
Flipgrid	Flipgrid is a video discussion tool. Students were required to use this tool to introduce themselves to their peers and game moderators.	3		
GooseChase	GooseChase is a mobile application that allows participants to complete virtual scavenger hunts. GooseChase missions require a variety of submission types, such as 300 characters of text, photos, or 15-second videos. Students were required to complete an individual and a team scavenger hunt.		3, 4	
Padlet	Padlet is a discussion board platform for virtual brainstorming, organization, and documentation using text, images, videos, links, and files. Students were required to use Padlet for team activities and PDR research documentation.	3, 4	2, 3, 4, 5, 6, 7	1, 2
Pronto	Pronto is a group video and text chat tool that allows users to text, video chat, livestream, file share, send announcements to groups, and translate languages. Throughout each level, students were required to communicate and collaborate with their teams and game moderators using Pronto.	3, 4, 5, 6	4, 5, 7	3
Qualtrics	Qualtrics is an online survey platform. Students were required to submit consent forms, formative assessments, and reflections using this platform.	1, 2, 5, 7	1, 8	4

TABLE 2. A description of the external tools, their purpose, and when they were used.

send announcements to groups, and translate languages. Throughout each level, students were required to communicate and collaborate with their teams and game moderators using Pronto. Because of the federal government IT security requirements and university institutional review board policies for working with minors, we were unable to use all of the features available in Pronto. Each team had a channel for communicating and collaborating that a game moderator monitored, answering team questions and making sure communications were professional. Students requested to also use the private chat feature of Pronto to easily collaborate with specific members of their team; however, since they were minors and university policy on working with minors recommends adult supervision of minors during all peer-to-peer activities, we were unable to use the private chat feature.

Five of the six tools were embedded in Canvas using the LTI feature: Badgr, Flipgrid, Padlet, Pronto, and Qualtrics. Using the LTI features allowed for seamless integrations, which connected Flipgrid, Padlet, and Qualtrics submissions to the gradebook. GooseChase was the only external tool that required a mobile device application. Badgr, Padlet, Pronto, and Qualtrics were used in each level of the course, while Flipgrid was only used in Level 1, and GooseChase was only used in Level 2.

Most of the elements from the proposed redesign (Figure 2) were included in the virtual experience; however, side quest challenges (aka bonus areas) were removed to avoid confusion or distraction from the overall purpose of the experience. Additionally, mention of a two-day onsite event as a completion reward was not included to avoid the need to reschedule the event in light of the pandemic. These changes resulted in three levels of the game—Level 1: Team Building, Level 2: PDR Builds, and Level 3: PDR Video Presentation. Each level progressively became more challenging and included multiple quests, which were designed for students to complete sequentially and aligned to the TEKS and NGSS. Table 3 describes each quest and aligns the overall focus of each quest to the relevant TEKS and NGSS engineering and design standards.

Level 1: Team Building

Level 1 promoted team building while learning important expeditionary skills like leadership, followership, teamwork, and communication. Students begin their Moonshot journey by completing the seven quests of Level 1 (see Table 3). Throughout this level, students communicated on Pronto as they worked in teams to create a team name, symbolic mission patch, and choose roles and responsibilities for their upcoming quests to ensure accountability from each team member over the five-day experience. There were nine teams in each section of the course, and each team had 10-13 team members with distinct roles and responsibilities during Levels 2 and 3.

Level 2: PDR Builds

Level 2 quests used the systems engineering approach to gather scientific research for mission planning to the lunar surface, mimicking NASA's Artemis Program. Using systems engineering—a jigsaw method—helped teams achieve the overall goals of getting to the lunar surface, living on the lunar surface, sustaining on the lunar surface, and eventually expanding to Mars. Students completed eight quests in Level 2 (see Table 3) and used Pronto and Padlet as main collaboration tools within their teams. Students were required to reach Quest 6 by mid-day on day two to receive an award: Attending a live round table with NASA engineers, scientists, and interns. If students did not reach Level 2, Quest 6 by this time, they were required to watch the recording of the live event.

It should be noted that the content learned within each team further aligns to science specific TEKS and NGSS; however, it is not provided in Table 3 as each team's mission focus was slightly different, resulting in different standards covered by each team.

Level 3: PDR Video Presentation

The four quests of Level 3 (see Table 3) required students to compile their mission-specific research and design a preliminary prototype with acceptable risk due to design constraints. Level 3 provided teams the opportunity to align their research with true industry requirements on a smaller scale. Teams created and recorded a PDR video presentation that presented a cohesive, technically sound human mission to the Moon as a final project.

Navigation in Canvas

The navigation of the course in Canvas was designed to emphasize the gamified elements and strengthen students' perception of the course as a game. To do this, the left-navigation bar was minimized to three items (Home, Grades,

<table>
<tr><th>QUEST</th><th>DESCRIPTION</th><th>TEKS ALIGNMENT</th><th>NGSS ALIGNMENT</th></tr>
<tr><td colspan="3">Level 1: Team Building</td><td></td></tr>
<tr><td>Quest 1</td><td>Defines expectations and professionalism etiquette during the gamified onsite experience. Students and their guardian sign consent forms allowing the student to advance to the next quest.</td><td rowspan="3">§130.402 Principles of Applied Engineering, Standards 1 and 9

§130.410 Engineering Design and Presentation I, Standards 1-4 and 7

§130.416 Biotechnology II, Standards 1 and 4

§130.417 Scientific Research and Design, Standard 1</td><td rowspan="7">HS-ETS1-3 Engineering Design</td></tr>
<tr><td>Quest 2</td><td>Students film an introductory video for their teammates and game moderators to watch; this icebreaker continues building connections between like-minded, goal-orientated students</td></tr>
<tr><td>Quest 3</td><td>Each team uses their Pronto team channel to create their team name which integrates their call sign (e.g., Alpha, Bravo, Charlie). Teams elect one person to post the name on Padlet. Active participation from each team member encourages and fosters increased development of team bonding, ownership of team decisions, and forward movement.</td></tr>
<tr><td>Quest 4</td><td>Team members collaborate using Pronto to design a team mission patch and write a description of the symbols used. The team elects one team member to upload the final patch and description to Padlet.</td><td rowspan="4">§130.402 Principles of Applied Engineering, Standards 1-2 and 9

§130.410 Engineering Design and Presentation I, Standards 1-4 and 7

§130.416 Biotechnology II, Standards 1 and 4

§130.417 Scientific Research and Design, Standard 1</td></tr>
<tr><td>Quest 5</td><td>Introduces the Artemis program goals and systems engineering approach to achieve a deep space exploration mission. Teams use Pronto to discuss the Artemis programs goals and systems engineering approach and vote individually on mission parameters (e.g., duration, crew size, how to prepare and train astronauts) using Qualtrics. Teams Alpha through India use the results to plan for Level 2 and 3 quests, where they will use a systems engineering path to advance human spaceflight.</td></tr>
<tr><td>Quest 6</td><td>Using Pronto, teams discuss roles and responsibilities for upcoming levels and collectively decide which role each member assumes Each role has specific tasks, which assist in accountability for each member.</td></tr>
<tr><td>Quest 7</td><td>Using Qualtrics, students reflect on the advantages of working with a team rather than individually and explain any challenges faced during the Level 1 quests.</td></tr>
</table>

TABLE 3. A description of the quests and their alignment to the TEKS (TEA, 2018) and NGSS (NGSS Lead States, 2013).
continued on next page

QUEST	DESCRIPTION	TEKS ALIGNMENT	NGSS ALIGNMENT
Level 2: PDR Build			
Quest 1	Almost all solutions at NASA require individual parts to work together as a whole. Teams learn about the benefits of systems engineering and reflect on the significance of this approach.	§130.402 Principles of Applied Engineering, Standards 1-2, 6, and 9 §130.410 Engineering Design and Presentation I, Standards 1-4, 7, and 9-10 §130.416 Biotechnology II, Standards 1, 4-5, and 7 §130.417 Scientific Research and Design, Standard 1, 4, 5, 7, and 10	HS-ETS1-2 Engineering Design HS-ETS1-3 Engineering Design HS-ETS1-4 Engineering Design
Quest 2	The "big picture" of the team's mission planning topics is revealed. Teams experience guided questions to discover mission goals, project subtopics, and a design challenge. Students post questions on Padlet asking game moderators for clarity about the mission.		
Quest 3	Students individually complete a GooseChase scavenger hunt to learn about NASA, NASA's Artemis mission, the International Space Station, the Commercial Crew Program, NASA's Internships and Pathways Program, and career paths at NASA. Students record information that may be important to their team's mission on Padlet.		
Quest 4	Students collaboratively complete a GooseChase scavenger hunt with their team to acquire knowledge specific to their mission subcomponents. Each team member then posts information learned that may be important to their team's mission on Padlet.		
Quest 5	Each team's systems engineer communicates using Pronto to help share information discovered on previous quests and align the goals of all teams. Team members communicate using Pronto to identify mission goals, select subtopics, and choose a design challenge, which the systems engineer posts on Padlet.		
Quest 6	Students participate in a live session with NASA engineers, scientists and interns to learn about NASA careers and technical specific knowledge to current missions. Students post notes on Padlet.		
Quest 7	Team members work on the specific components for their team role. Students use Pronto and Padlet to finalize scientific research		
Quest 8	Students use Qualtrics to reflect on team roles, research and design tactics, and the purpose of systems engineering.		
Level 3: PDR Presentation			
Quest 1	Teams review PDR video presentation requirements and expectations. Students ask questions to game moderators using Pronto and Padlet.	§130.402 Principles of Applied Engineering, Standards 1,3, and 9 §130.410 Engineering Design and Presentation I, Standards 1, 3-4, and 7 §130.417 Scientific Research and Design, Standard 1 and 10	HS-ETS1-3 Engineering Design
Quest 2	Teams use Pronto to discuss and assign the scripts and slides for the PDR video presentation. The integration manager constructs a timeline to complete all tasks.		
Quest 3	Teams create a 12-15-minute group video presentation explaining the team's PDR. Once completed, the integration manager edits and uploads the video presentation		
Quest 4	Students provide feedback on the overall Moonshot course and how it impacted their knowledge and understanding of STEM, NASA's research and developments, upcoming missions, and NASA careers and other opportunities.		

TABLE 3 (CONT). A description of the quests and their alignment to the TEKS (TEA, 2018) and NGSS (NGSS Lead States, 2013).

and Badges), and the home page depicted a map of all three levels (see Figure 3). Level 1: Team Building was situated on Earth, Level 2: PDR Builds was situated on the Moon, and Level 3: PDR Video Presentation was situated on Mars. Our team's instructional designer used the map graphics to create clickable, html image maps that were embedded in Canvas pages.

Students navigated through the course by first selecting their level; once they landed on their level's map, they would select their quest. After completing each quest, students were routed to a map of their current level that added a green check to all of their completed quests and instructed them to access the next quest (see Figure 4). When completing the last quest in a level, a "Ready to" patch covered the completed level map (see Figure 5) and routed students to a version of the homepage map that included a green check over the levels that were complete (see Figure 6). From start to finish, students accessed 26 html image maps to navigate through the course.

USERS' EXPERIENCE OF THE DESIGN

There were two distinct rounds of beta testing before Moonshot went live with students, and two rounds of implementation occurred with students.

Beta Testing

The first round of beta testing was conducted with 11 NSPACE employees and HAS alumni working as NASA summer interns. The beta testers used a wide variety of devices (e.g., phone, iPad, Macbook, PC) as well as a variety of browsers (e.g., Chrome, Edge, Safari). As the beta testers encountered problems, they submitted a survey using Qualtrics to document the issue, and if the encountered problem prevented them from moving on, they sought help from the beta testing game moderators (design team

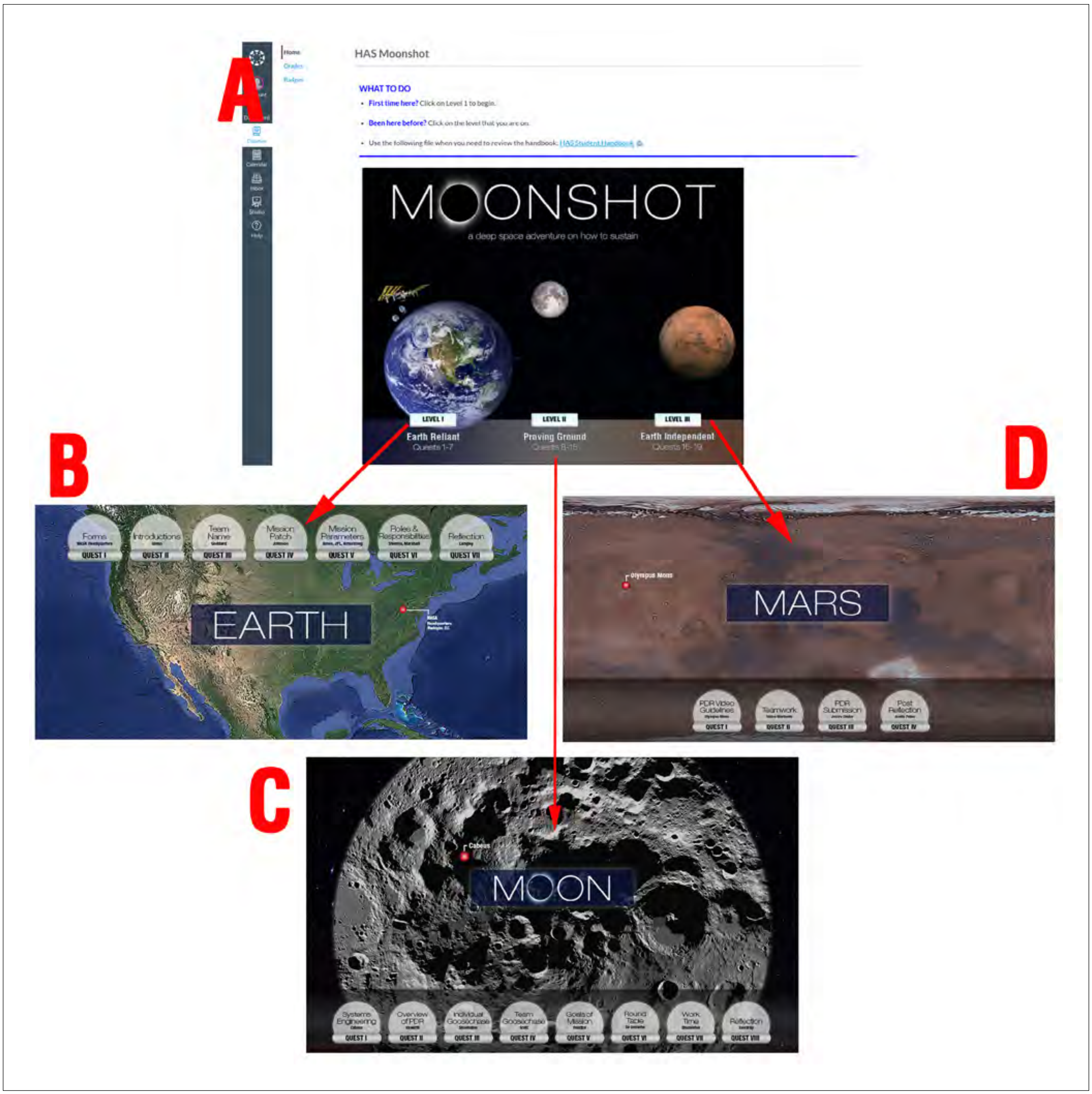

FIGURE 3. The home page (A) allows students to navigate to each level: Level 1—Earth (B), Level 2—the Moon (C), and Level 3—Mars (D). Students access quests from within the level maps.

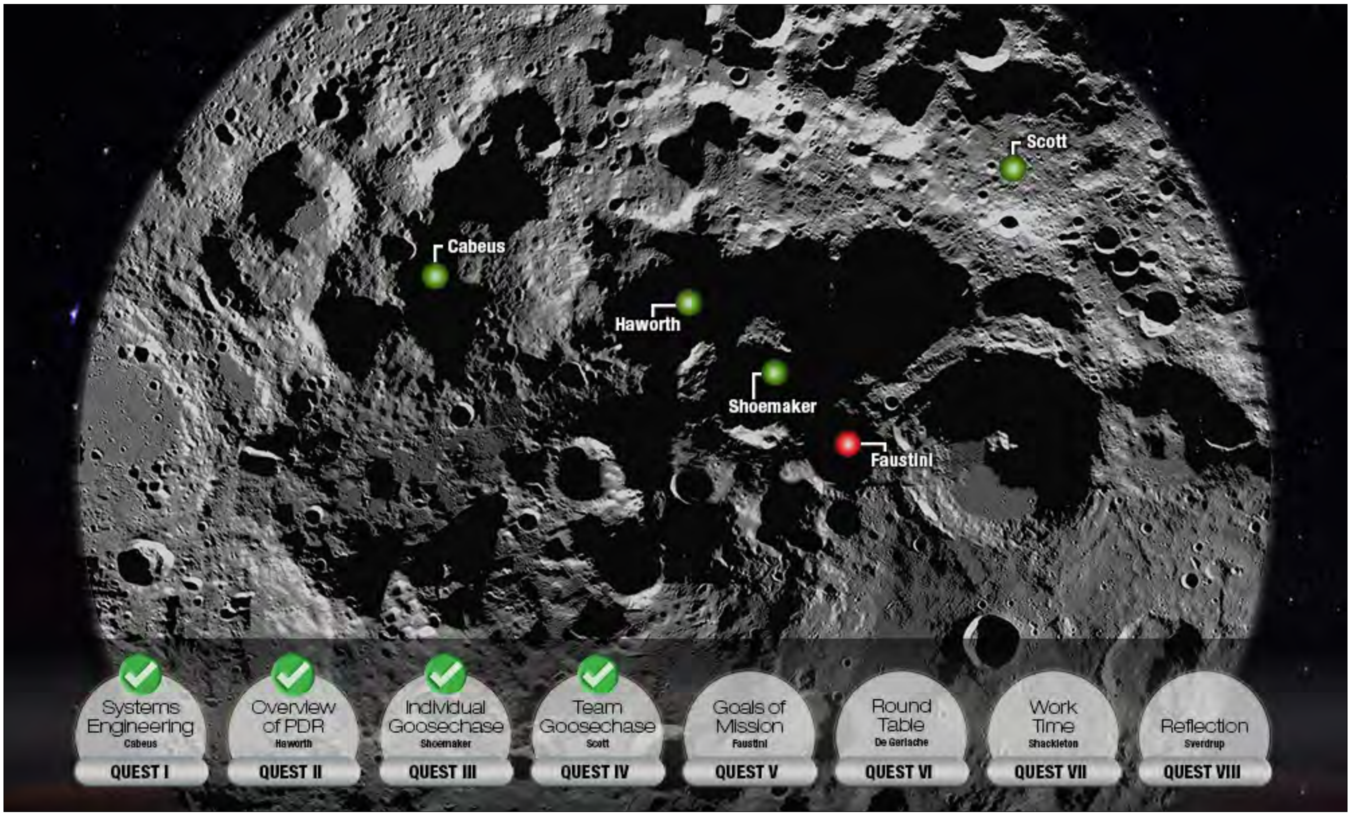

FIGURE 4. Map depicting that students have completed Level 2 Quests 1-4 and are ready for Level 2, Quest 5.

FIGURE 5. Map depicting that "Ready to" patch that students see when they have completed the final quest in a level and are ready to progress to the next level.

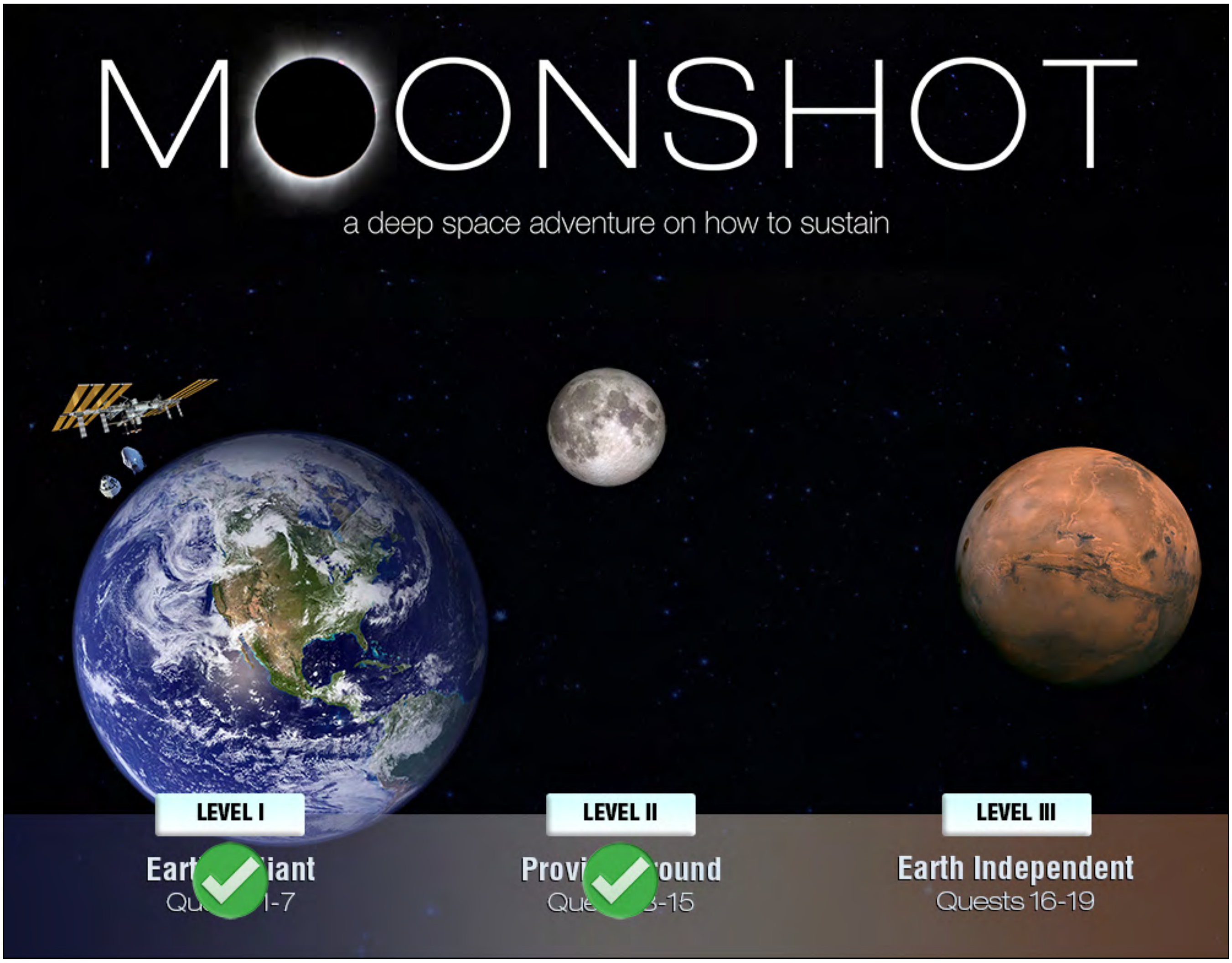

FIGURE 6. Map depicting that students have completed Levels 1-2 and are ready for Level 3.

members). At the completion of testing, the beta testers submitted a final survey asking them to provide feedback on the overall course.

Despite some navigation problems (see Design Failures, below), the beta testers described the course as engaging, interactive, and collaborative, making it unlike any other online course they have experienced. They believed students would be able to complete the work in five days. Additionally, they indicated the course would encourage students to seek out other opportunities at NASA, recognize the importance of the work done by NASA, enhance academic and career interests, develop knowledge of the engineering design process, increase teamwork skills, and encourage the use of research.

Revisions were made to the course based on the initial beta testers' feedback, and the second round of beta testing was conducted with the nine game moderators after the revisions had been made. Almost all (7) of the game moderators had previously served as a HAS onsite counselor, so they had a high level of familiarity with the content. Members of the design team—including the NSPACE PI, NSPACE lead education coordinator, STEM collaborations lead coordinator, HAS education specialists, and instructional designer—provided professional development to support the game moderators' understanding of the best practices of online teaching and how to use all of the technology included in the course. After this professional development, the HAS staff acted as moderators while the game moderators worked through each quest of Moonshot as a student, which allowed them to fully understand what students would be asked to do. They were excited by the gamified design, assisted each other using Pronto chat and livestreams when someone got stuck, and were competitive. They believed students would be able to complete the work and described that it would be important for students to thoroughly read and follow all of the instructions. The only thing the game moderators requested were printable versions of the rubrics for their personal use during grading.

Once the second round of beta testing was complete, our instructional designer imported the revised course into the six course sections that would be used during the student implementation. Because we wanted students to only participate and interact with the students in their section, we had to create copies of each Flipgrid, Padlet, and one Qualtrics survey where students voted on their mission parameters. Each team GooseChase had a distinct password that would prevent members from other sections from accidentally participating in another team's scavenger hunt. Finally, our instructional designer edited the html for each of the 26 html image maps to create new image maps for each section that linked students to the quests and levels of the section that they were enrolled in.

Student Implementation

Moonshot was implemented with students over two weeks, and the game moderators facilitated three sections each week. Of the 611 students registered to participate, 573 students (94%) completed the course; 21 students (3%) started but did not finish, and 17 students (3%) did not participate at all. Students, game moderators, NASA consultants, and HAS staff completed reflective surveys at the end of each week of implementation.

Overall, students valued and were engaged with the online experience. They indicated they had a better understanding of NASA and careers at NASA and were more likely to be involved in STEM and use their STEM content knowledge to solve problems after completing the course. For instance, one student reflected, "NASA HAS has taught me an extensive amount about myself. I've learned about my interests, increased my patience, and have developed more grit for difficult tasks. NASA HAS has proved to me, in a roundabout way, that the Air Force is a path I am capable of taking." Another student described, "I have really enjoyed this program. It has allowed me to discover skills I did not know I had. I also learned so much about NASA and STEM fields. This program has pushed me to become a better team member and STEM student." Although the overall learning effects met the course objectives, students noted problems communicating with team members, a lack of detail in rubrics, the desire for a more concrete schedule, and the need for more accountability measures for team members who did not contribute (see Design Failures, below).

The game moderators served three teams each week; one team in each section (e.g., Alpha 1, Alpha 2, and Alpha 3 in Week 1). Overall, the game moderators noted that students were engaged and navigated the quests with ease; however, the game moderators felt disconnected from the teams they were serving and had a hard time connecting with students. While the students frequently used Pronto to communicate and collaborate with each other, it was difficult for the game moderators to filter through the messages and keep up with the chats.

The HAS staff supported the game moderators by overseeing each week of implementation. They were impressed by students' engagement and quest submissions. In fact, they believed that the strategic use of tools and design of the course did a better job of capturing students' learning than the onsite event at JSC. Despite being impressed by student outcomes, the HAS staff noted the need for more training with game moderators and NASA consultants as well as problems with some of the external tools (see Design Failures, below).

DESIGN FAILURES

Although the design decisions adequately addressed the gaming principles (Bonk & Dennen, 2005) and gamified elements (Kopcha et al., 2016), the beta testers, game moderators, students, and HAS staff identified several design failures during beta testing and the student implementation.

Beta Testing

To identify possible issues with different devices and browsers, we intentionally requested our beta testers use a variety of devices and browsers to test the Moonshot course. We quickly found out that the Canvas Student app would prevent students from seeing all of the maps, which were created by embedding html files with clickable images into a Canvas page; this would be problematic because the only way students could navigate the course was through the maps. Additionally, preferences in Safari typically prevented the images from showing up on both mobile devices and computers. Google Chrome and Microsoft Edge both allowed all beta testers to access the course and navigate between the quests and levels. Because all students indicated they had a computer to participate in Moonshot, the HAS staff used this information to recommend that game moderators and students access the course using one of these two browsers on their computers.

In addition to providing valuable information about how to access the course, the first group of beta testers identified a significant flaw with the course's navigation. The navigational issue occurred after the beta testers submitted team quests that were assigned as group assignments in Canvas. Normally, group assignments in Canvas are set up so all students in a course are assigned to a group, and all groups are contained in a particular group set; however, there were two specific design problems that prevented us from using group sets in this way. First, for the majority of the team quests in Level 2, each team needed to access a Padlet specific to their team, which we wanted to embed in the assignment rather than having students navigate to an external website. Second, we had to create a group set for each team to provide teams with a Pronto chat channel that

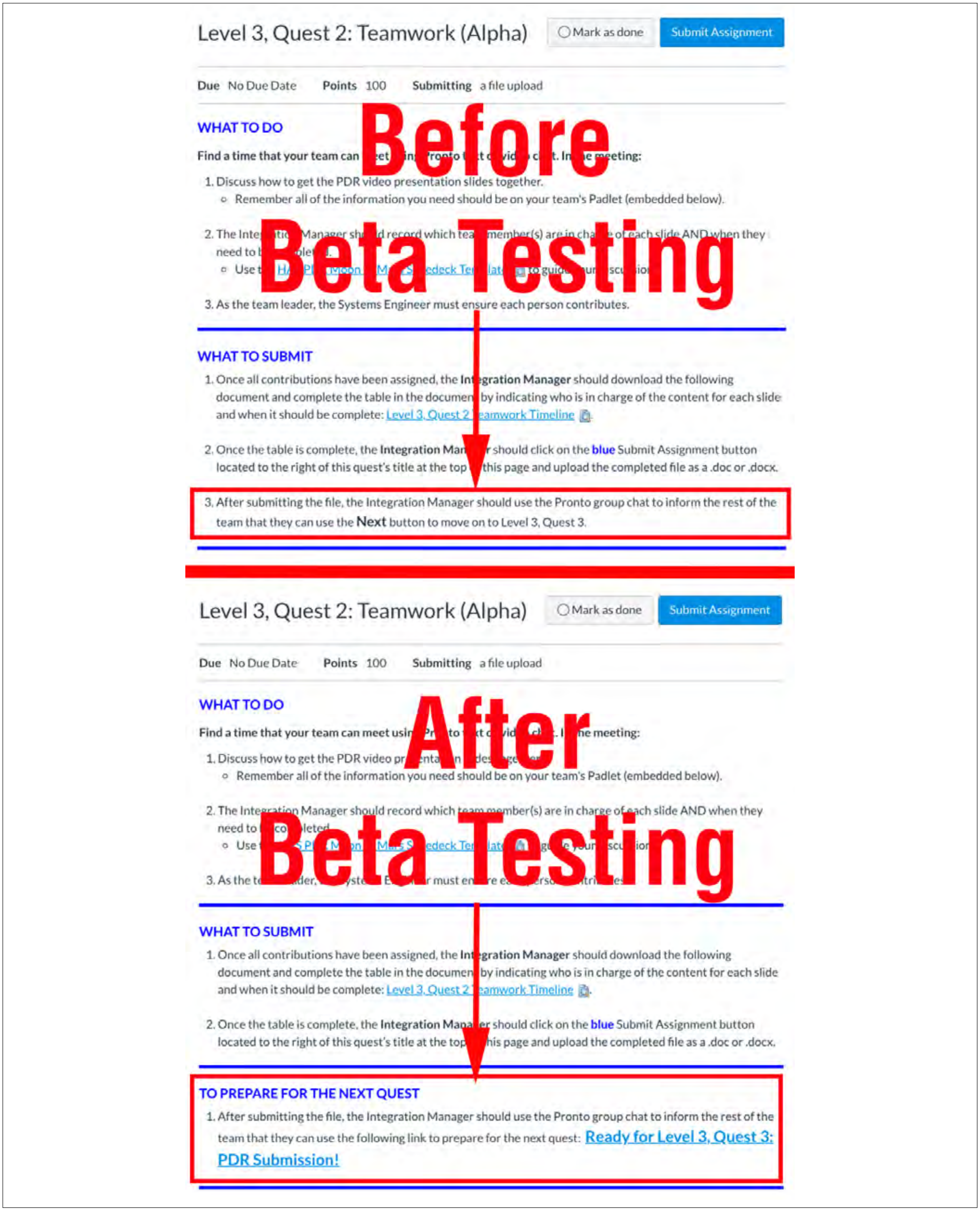

FIGURE 7. Images depicting navigation instructions before beta testing, and the revisions made to those instructions after beta testing.

was specific to their team; assigning a team's assignment to their group set would not prevent other students from accessing it because the other students were not assigned to another group in that set. In the beta testers' iteration of the course, the student instructions and navigation were designed so students would click the "Next" button at the bottom of a Canvas assignment to navigate to the map before continuing on to the next quest and/or level; however, because students were in different group sets and could access another group's assignment, a student in Alpha would have to push the "Next" button nine times to get through all the team assignment pages before they finally reached the map that would take them to the next quest and/or level. There were nine group assignments overall—one in Level 1, six in Level 2, and two in Level 3.

To eliminate this design failure, we updated the design by adding instructions to all quests—individual and team—that required students to click on a link to "Prepare for the next quest" (see Figure 7). The HAS staff demonstrated and emphasized the need to follow these instructions during the orientations for the game moderators and students. As a result, neither the game moderators nor the students experienced problems navigating Moonshot from the student view.

Student Implementation

During the student implementation, students, game moderators, and HAS staff all experienced problems with communication. Pronto intentionally was chosen because it allowed group text chats, group video chats, file sharing, and livestreaming for up to 400 people. It served its purpose perfectly for students communicating within their groups, enabling distributed learning, multiple routes, practice, probing, application of STEM concepts, and reflection; however, Pronto failed in efficiently connecting students with their game moderator and supporting the needs of the game moderators and HAS staff. It was difficult for the game moderators to filter through the messages and keep up with the chats of the three teams they were moderating each week. One moderator noted stepping away from the computer for a few hours and coming back to hundreds of messages to sort through. As a result, most of the game moderators were often unsure of how or when to interact with students and felt disconnected from their teams.

The HAS staff planned to use Pronto livestream for daily sessions to connect participants, game moderators, HAS staff, and NASA consultants, with assurance from Pronto their product would support 400 attendees in a livestream session. Over 350 attendees tried logging into the first session during week one, and the HAS staff quickly realized

FIGURE 8. Video of closing ceremony event with NASA Astronaut Mike Fincke. Retrieved from https://youtu.be/JCWNxsLwg0c

microphones and video streaming lagged. Additionally, attendees could not get into the session once the numbers reached over 100 participants. The event was immediately cancelled due to the system not having the capability of supporting large audiences. The HAS staff brainstormed how to resolve the problem, and the solution required the HAS staff to divide the participants into two smaller groups and host events through Microsoft Teams. The HAS staff used the Pronto announcement function to send Microsoft Teams links to the students.

The closing ceremony was a much larger webinar, hosting over 600 individuals from both weeks of the virtual onsite. The HAS staff shared the Microsoft Teams platform through the NASA Johnson Space Center YouTube account. During the event, guest speaker Astronaut Mike Fincke delivered a speech and answered questions from eight HAS students. The Microsoft Teams link was only sent to the speakers; all other attendees joined through an unlisted YouTube livestream (see Figure 8). One week after the event, the closing ceremony had over 1,200 views.

At the end of each level, students submitted a reflective survey about their Moonshot experiences. The final quest's survey revealed that the majority of students were thankful for the experience, specifically noting it was the most engaging and collaborative online course they had ever taken. One student described, "Even online, this program was certainly effective at fostering collaboration and a sense of camaraderie. I loved working with the people in my team, and I hope to see them around in the future one day! Additionally, I wholeheartedly appreciated the level of humanity emphasized through the organization many associate with strict science. This truly was a wonderful experience!" Despite the overwhelmingly positive feedback, four failures emerged from the three end-of-level surveys to address in future iterations of the course. First, students expressed that the rubrics for some quests lacked detail, leaving them unsure of how they were going to be evaluated; these rubrics will be evaluated and refined. One student commented, "I feel that with a more detailed rubric, I would better know my responsibilities."

The remaining three failures were associated with students working as a team. Some students desired a more concrete schedule. For instance, one student explained, "I think it is important to have a set schedule to follow. Even though the freedom to meet and work at any time was nice, I think providing a schedule such as opening circle where you highlight today's goals and have breakout rooms to meet other scholars would be nice, or even do a fun activity." A schedule was sent to students at least a week and a half before the start of Moonshot, provided in the handbook, and covered during orientation, and it indicated that a certain number of quests should be completed by a certain time each day to unlock an award (e.g., Live session with NASA consultants); however, some students would have preferred each quest and level to have a specific due date and time. In an attempt to be mindful of students' schedules while at home during the summer, we intentionally designed the course so there were not specific due dates and times for each quest; however, we may want to build in suggested due dates and times to keep students on track with the rest of their team. We also intend to send the schedule to students much earlier, so they can plan how Moonshot will fit with their schedules for work, athletics, and other extra curriculars.

In addition to a more concrete schedule, students would prefer fewer people on each team because there would be fewer schedules to coordinate with, making all of the collaborative meetings and tasks easier to schedule and complete. One student shared, "We could figure out our schedules a bit better. We had troubles with some people not available when we needed them."

Students also desired measures of accountability for their peers who were not contributing or responding to the rest of their team. When describing what could have worked better, one student explained, "There should be more accountability for participating. One of our team members was inactive for some time, so we had to take on his work." Another student suggested, "Try and enforce the idea that everyone on the team must cooperate, to complete this on time." Each team member had a specific role with its own responsibilities, and some of those roles required more work from students. Making this more explicit with students and having set times for game moderators to check in with each team may have reminded students about the responsibilities associated with their role and the overall team's dependence on each student doing their part.

As a result of feeling disconnected from students, several game moderators requested being assigned to fewer teams in future iterations, which will require the HAS staff to hire and train more game moderators.

Finally, the HAS staff expressed the need for more training with both the NASA consultants and game moderators. The NASA consultants needed training about what was needed and expected of them; it may have also been helpful to demonstrate the flow and progression of the course. The game moderators needed more experience navigating Moonshot from the teaching assistant side. The HAS staff noted that some moderators experienced issues identifying when they were required to grade individual assignments versus group assignments. Additionally, they noted the moderators needing more training and experience using the variety of tools that were integrated in the course. As it was, the game moderators had a little over a week between their professional development and the first week of implementation.

Traditional versus Virtual Onsite

The majority of the traditional HAS onsite experience translated well to the virtual Moonshot course; however, there were several aspects of the traditional onsite that were lost in the virtual setting. While at JSC, students tour multiple NASA facilities, including but not limited to, Christopher C. Kraft Jr. Mission Control Center, Space Vehicle Mock-up Facility, Sonny Carter Training Facility, and Rocket Park. Students were unable to experience the visceral feeling of walking the halls of the "working buildings" and touring NASA's unique facilities and assets for the first time during the virtual Moonshot course. Having students physically onsite helps them see themselves in an actual NASA career, which is one of the goals of HAS.

The second component lost in the virtual environment was the informal networking with members of the NASA workforce. While onsite at JSC, students encounter informal conversations with NASA consultants and subject matter experts. The NASA workforce receives an open invitation to eat lunch with the students throughout the week to share their NASA story, educational background, and answer other questions students have. The virtual environment limited informal networking opportunities and student access to the diverse NASA workforce. The NASA consultants identified this as an element they most look forward to during the onsite experience and missed in the virtual environment. This motivating opportunity helps HAS meet the goal of preparing the next generation of STEM workers.

The last elements we were unable to include were the opportunities for students to intermingle with their peers on other teams. During the onsite at JSC, students have the opportunity to network with each other at meals, in transit on the bus, at the hotel, and with their roommates. Traditionally, students are assigned to a sub-team, identified as their flight control team, which is made up of at least one person from each of the four teams. Students eat lunch and launch rockets with their flight control team. One of the goals of the NSPACE cooperative agreement is to facilitate students' progression on a pathway of NASA activities, and relationship-building with peers and NASA personnel is an important factor in meeting this goal.

IMPLICATIONS FOR US AS DESIGNERS

While the learning objectives were met and student products throughout each level of the gamified course surpassed products typically created in the traditional version of the course, it wasn't without a cost. Students did miss out on what often has been described as a "life-changing experience" spending a week onsite at JSC, participating in facility tours the general public does not have access to, having formal and informal mentoring from NASA scientists and engineers, and engaging in authentic challenges with like-minded peers. Video tours of facilities, formal video conferences with NASA consultants, and open text and video chat through Pronto were used to compensate in some way. One student expressed frustration with communication, noting what did not work well: "Communication between teammates as some people don't respond in the Pronto and I had to do someone else's work because we were down a whole member." This would have been alleviated in the onsite experience as participants spend significant time together. Enhancing the NASA consultant and game moderator trainings may help set expectations and identify ways to increase networking opportunities with students. We are looking for ways to incorporate student intermingling into the virtual course and will seek input from both the NASA consultants and game moderators as we move forward.

Other implications for us as designers are related to the logistics of work. The design of a course like this—one that is gamified, highly collaborative, and interactive—took a talented, well-qualified, and diverse team to design and develop. The amount of content created for the overall course as well as the content created for each team Alpha through India could not have been developed and tested by a single person in the timeframe we had (nine weeks). Much like the systems engineering built into the course, each member of our design team had a distinct role that contributed to the success of the course's design and implementation.

In order to design, develop, and deliver a project of this magnitude in less than three months, a large, talented team was required. Working from home all over the country during a pandemic, however, made even an outstanding team have to adjust typical processes. In the initial design team meetings, it became clear a variety of regular subgroup meetings would be necessary. None of this would have been possible without regular meetings and an organized location to brainstorm and share developed content.

The selection of one shared space—Microsoft Teams—that all team members could access anytime, anywhere allowed us to manage individual, subgroup, and full team files, communication, and research records. Microsoft Teams afforded us a space where we could embed our OneNote planning notebook, create multiple channels to store and share files associated with different subgroups (e.g., Budget and Finance, Evaluation, IT Systems), communicate via chat synchronously and asynchronously, and host virtual meetings with video and/or audio.

Although having a record of the plans and notes in OneNote was extremely helpful and was referred to regularly in meetings, different members of the design team held different pieces of information that, even with a digital collaboration tool, were not well-understood by all design team members. Often during meetings, we found it would be helpful to have someone not in that subgroup attending the meeting. In the future, it might be helpful for personnel in specific roles to be "on call" if needed for certain meetings.

CONCLUSION

Our goal was to develop a gamified, online version of the HAS six-day, residential experience at Johnson Space Center. Guided by gaming principles and elements, we conceptualized a theme; evaluated external tools that could easily be integrated with Canvas and met federal IT security standards; and designed and developed three levels,19 quests, and an intricate navigation in just nine weeks. Of all the design failures that students, game moderators, and HAS staff experienced, the two most prominent and problematic were resolved and did not negatively affect students' experiences. The navigation issues were resolved before the game moderators and students were enrolled in Moonshot, and the HAS staff nimbly shifted the live NASA consultant sessions from Pronto to Microsoft Teams.

While the COVID-19 pandemic prevented over 250 high school students from coming to JSC, Moonshot expanded the reach of the experience to more than double the number of students that HAS would have been able to bring onsite. Moonshot not only engaged 573 students in STEM content knowledge, problem solving, decision making, and teamwork, but also it made each student eligible for an additional half credit of an elective high school science credit, which would equate to one credit of an elective high school science credit when combined with the half credit students were eligible for after completing the 16-week winter online course. We are encouraged by students' learning outcomes and the positive experience students had as a whole. The NSPACE PI expressed that meeting this challenge of a virtual gamified experience would only serve to improve all of NSPACE's regular online activities and has already allowed NSPACE to expand its reach. Although Moonshot was available specifically to students in Texas, its alignment to the NGSS opens the door for replicating the program and increasing its impact on student outcomes outside the borders of Texas. We look forward to making additional revisions to the course to improve it for future HAS onsite experiences—whether they are virtual, at JSC, or another NASA center.

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