COMPUTATIONAL THINKING IN ECOSYSTEMS

EVALUATION REPORT

This report summarizes evaluative findings from the external evaluation of the CT-E project and its Design Based Research process.

Rockman et al

INTRODUCTION

This report summarizes evaluative findings from Computational Thinking in Ecosystems project, and the resulting product, i.e., a functional draft of a game called “The Pack,” funded though a grant by the National Science Foundation (grant number DRL-1543144). Specifically the evaluation sought to provide feedback on the game as it evolved through a series of early iterations. Evaluative efforts included gathering feedback from key stakeholders—including members of the design based research (DBR) team members at the New York Hall of Science (NYSCI) along with advisors and project partners—about the game and the DBR process, as well as an independent assessment of the game via feedback from educators and a round of play-testing with youth. The core goal of the formative evaluation effort was to determine the extent to which the DBR process and initial iterations of the game were aligned with stakeholder expectations and stated project goals. A subsequent summative evaluation effort sought to determine the extent to which the resulting iteration of the game met stated project objectives—i.e., to provide an innovative way for students to explore computational and systems thinking concepts and for teachers to be able to cover these concepts in an engaging and effective fashion.

Evaluation findings suggest that the iterative DBR process was largely successful in its efforts to produce an engaging and effective product that fosters development of computational thinking and systems thinking skills. The evaluation team found that there was great interest and enthusiasm among those who participated in the game design process. Timely research was conducted by an internal research team following each iteration of the game that was released. The results of those research efforts helped to drive subsequent revision and improvements within the game. Efforts to streamline communication between members of the DBR team—especially the lead designers and members of NYSCI’s internal research team—helped to enhance the efficacy of the iterative design process. Environmental science experts as well as a team of educators were also called upon to provide input and feedback that helped to inform the iterative design process in meaningful ways.

This report seeks to draw conclusions about the DBR process and its ability to bring about desired programmatic outcomes. It explores challenges to the DBR process as well as ways that the team ultimately sought to overcome those challenges. Five key challenges were identified, including 1) determining whether this was a computational thinking game with an environmental science focus or an environmental science game that incorporated computational thinking strategies and gameplay mechanics, 2) narrowing down the focus to a manageable set of content and gameplay objectives, 3) balancing design considerations related to in-school and out-of school usage contexts, 4) balancing the need for some structured gameplay components and objectives despite the overarching desire for this to be an open-ended gameplay experience, and 5) striking the right balance between close adherence to the way things are in the real world and meaningful use of fictional elements.

This report also presents an independent assessment of the extent to which the final product (i.e., the iteration of the game that served as the final deliverable of the NSF-funded initiative) was able to accomplish intended objectives—from the perspective of both educators and youth. Feedback from teachers and youth in the target age-range for the game suggest that “The Pack” holds great potential as a resource for introducing and enhancing understanding of computational and systems thinking skills. The game is engaging and succeeds in successfully holding the attention and interest of youth of various ages and skill levels and also seems to be fostering meaningful thought on relevant topics. Furthermore, teachers can readily identify ways it could be used to help cover related curriculum.

INTRODUCTION

Rockman et al (REA), an independent research and evaluation firm with extensive experience evaluating projects that combine technology tools and STEM learning, served as the external evaluator for the New York Hall of Science' CT-E project. The overall goal of the CT-E project's external evaluation was to provide objective information about emerging iterations of the game and the resulting potential to help students develop computational thinking skills as well as a deeper understanding of environmental systems.

During the first phase of the project, the evaluation team focused on answering formative evaluation questions related to the development and modification of early iterations of the "The Pack" game.

FORMATIVE EVALUATION QUESTIONS

1. **DBR PROCESS:** How effective is the DBR process in aligning game development with learning outcomes? How are all the perspectives and feedback, from the DBR team, including teachers, and students, incorporated into the development of the game and companion resources?
2. **CHALLENGES & RECOMMENDATIONS:** What challenges or recommendations emerge during Phase 1, and how does the DBR team incorporate these into subsequent iterations?
3. **TEACHER PERSPECTIVE:** What are teachers' perceptions of the ways the various game design elements—the narrative, mechanics, feedback features—will lead to the learning outcomes for students? Do teachers see CT-E as a viable way to integrate computing into STEM subjects and meet the NGSS standards and core requirements of the science disciplines? How do they see the game being used in less structured settings?
4. **STUDENT PERSPECTIVE:** What are students' perceptions of the game's features, goals, and play experience?

During the second phase of the project, evaluators continued to examine the DBR process, but also turned greater attention to summative assessment of the final deliverable and related outcomes.

SUMMATIVE EVALUATION QUESTIONS

1. **DBR PROCESS:** How well do the research findings and development decisions follow from the gathered evidence? To what extent does this project meet its objectives and deliverables? Does CT-E provide an effective, scalable model for helping students engage in computational, systems thinking, and for linking science learning and science practice?
2. **TEACHER PERSPECTIVE:** How teachers respond to the game? What do teachers perceive as the barriers to computational thinking and learning complex environmental science concepts? Does the game give them, and students, tools to overcome these barriers?
3. **STUDENT PERSPECTIVE:** What evidence suggests that the game helps students develop and apply computational and systems thinking skills? Where are the gaps, and what further development is needed to address them?

INTRODUCTION

METHODS

The following methods were employed by the evaluation team to gather feedback and draw evaluative conclusions about the DBR process and the resulting prototype of the game that was developed during the NSF-funded period of this project.

STAKEHOLDER INTERVIEWS

The evaluation team developed a series of stakeholder interview protocols (copies of which can be found in Appendix A), and conducted numerous in-depth interviews with various members of the DBR team at key stages during the design process. Over the course of this project, the evaluation team conducted six rounds of stakeholder interviews and a total of thirty interviews.

EDUCATOR SESSION OBSERVATIONS AND FOCUS GROUPS

A series of brainstorming and feedback sessions with educators, led by members of the DBR team, were observed by members of the evaluation team over the course of this project. Focus group sessions were also led by a member of the evaluation team on three occasions at various points—roughly equating to a beginning (October 2016), middle (May 2018) and end-point (December 2018) within the project.

YOUTH PLAY-TESTING SESSIONS

In December of 2018, the evaluation team led a series of play-testing sessions with middle school-aged youth in Bloomington, IN. These sessions employed a think-aloud protocol wherein youth were invited to play "The Pack" for 30-40 minutes and were prompted by a member of the evaluation team to explain more about what they were doing or thinking at each stage of play. Following each play session, the evaluator leading the play-testing sessions conducted an interview with participants to glean additional insights into the play experience, including feedback about the game's appeal and a basic assessment of perceived learning outcomes.

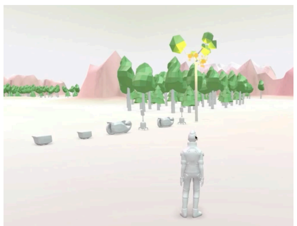
DATA ANALYSIS AND SYNTHESIS

Following each round of data collection, members of the evaluation team have employed qualitative analysis procedures to identify patterns and themes within each set of data and across multiple data sets. The underlying goals of these evaluative efforts were determining the extent to which the DBR process and resulting iterations of the game were in alignment with the DBR team's expectations and accomplishing overall project-level goals.

INTRODUCTION

ABOUT THE GAME

“The Pack” is a STEM game that seeks to foster development of computational thinking skills along with a deeper understanding of environmental science concepts. There were five key iterations of the game examined as part of the external evaluation—details of which are described briefly below.



PRE-ALPHA

- Different creatures can be collected and added into a player’s “pack”
- Different combinations and orders of creatures are required to accomplish different tasks
- DBR Team members responded positively to this initial exploration of the concept

ALPHA 1

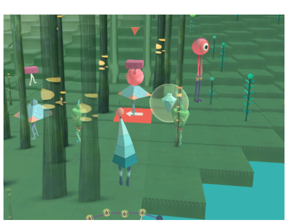
- Virtual world with many regions/biomes to explore (albeit static biomes)
- Creatures found in various regions; players must collect the correct kind of “food” to lure each creature to the pack
- Less focused on computational thinking elements but did explore environmental science topics
- Playtesters found it engaging to collect animals (& played for long-periods)

ALPHA 2

- Focused on the “creature functionality component” of the game, i.e., exploring the effects of different creatures on a single environmental space
- Using the pack of creatures as a representation of an algorithm

PROTOTYPE 3: “BETA”

- There were a series of additional iterations of the game evaluated by project stakeholders and members of the evaluation team
- One featured specific biomes that could evolve in different ways
- Later iterations were more similar to the public beta, but featured different amounts and constraints related to resources, i.e., characters and food



PUBLIC BETA

- Provided adequate access to food and characters
- Fosters sustained play and thought about computational thinking
- Enabled players to build stackable algorithms to complete tasks—however, initial testing suggests more prompts might be necessary to promote use of more sophisticated algorithms

FINDINGS: SECTION ONE

REFLECTIONS ON THE DESIGN BASED RESEARCH PROCESS

Introduction

One of the primary objectives of the external evaluation was to study the Design Based Research (DBR) process—identifying strengths and challenges, subsequent solutions, and outcomes. Through observations of stakeholder meetings, review of the research team's reports, and interviews with DBR team members/stakeholders and teachers, members of the evaluation sought to identify apparent strengths and challenges with the DBR process. Specific findings uncovered through these evaluative efforts are summarized below.

Strengths of the DBR Process

Among the many strengths of the DBR process, the following were most notable in this project: the research process—including strategies for addressing feedback and adopting recommendations—and the DBR team itself. Each are described in greater detail below.

THE RESEARCH PROCESS

Research efforts yielded meaningful findings, even on tight timelines. There seemed to be agreement among team members and project stakeholders that the research team was able to effectively mobilize to conduct testing quickly and provide timely feedback about how youth were interpreting and responding to each iteration of the game, and "it was a relief for designers to be able to send something that they are working on and know that kids have been able to play it and be able to get feedback." Over the course of the project, the research team managed to get the time necessary to provide feedback down to about a week and a half—from delivery of a new prototype, developing a plan and getting it approved, conducting testing, analyzing results and reporting them out to the team. In the later stages of the project, members of the research team were given direct access to the designers; by streamlining communication in this way, there were additional benefits. Researchers sought to provide feedback in strategic ways, meant to tell the designers what was most needed—emphasizing information they were most interested in knowing. Furthermore, by reducing the number of steps involved in communicating information, requests for research and resulting findings could be communicated more expediently. Ultimately, the information collected and shared by the research team enabled ongoing iterative design initiatives that were well-informed.

Researchers were creative and proactive in terms of how they approached testing various concepts and game elements. Stakeholders valued the research team's flexibility and their efforts to pivot or adapt efforts based on available testing resources in each round of testing. Some prototypes of the game required more contextualization and elaboration on the part of researchers to facilitate meaningful and effective play-testing. In one instance, researchers conducted a round of testing with youth using pieces made out of felt in order to gain insights into how they broke more complex actions (e.g., digging a hole), up into simpler steps, and how they thought about the intention or purpose of different types of creatures.

FINDINGS: SECTION ONE

REFLECTIONS ON THE DESIGN BASED RESEARCH PROCESS

The process ensures that the voices of end-users are being heard and that their needs are subsequently being served. By incorporating feedback from a diverse group of users, including a mix of genders, ages, ethnicities, academic ability levels and interests and gaming fans as well as those who are less into gaming, the DBR process sought to ensure that the game would ultimately appeal to a wide range of players. "As a producer, you create a product and think it's going to be great, but then it doesn't always turn out that way," explained one DBR team member, "the process helps to inform what is actually working and make changes to serve the target audience."

The research team effectively contextualized game-based components and experiences. Play-testing sessions conducted by the research team required additional supports and efforts to help play-testers contextualize early iterations of the game that were understandably not complete or standalone gaming experiences. Researchers were also skilled at assembling and presenting post-play feedback in such a way that responses and suggestions were conducive to informing the ongoing iterative design process. To facilitate the research process, the research team also adopted a set of personas that helped them theorize reactions and outcomes to game prototypes across a range of potential users in the target age-range. These personas were designed to help identify different potential responses to the gameplay experience.

The DBR process was responsive to team member's feedback and recommendations. According to team members, a successful DBR experience is one in which the iterative design process is responsive and effectively incorporates vital feedback from all team members at each phase. Responsibility for helping to identify problems or potential issues with evolving iterations of the game was shared among all team members, but—by design—not all team members were actively involved in the process of identifying solutions. Nonetheless, DBR team members felt that their feedback was considered and that their contributions in the form of comments, ideas, and shared resources were valued contributions to the game design process. "The designers take feedback very seriously," noted one DBR Team member.

One of the most poignant examples of a team members' feedback being addressed effectively related to one of the characters in the "Alpha 1" version of the game. Early on in the design process, several stakeholders voiced concerns about a humanoid character who acquired feathers in his headdress as he moved around the game-world adopting creatures into his pack—conjuring notions of Native Americans and thus sparking concerns about cultural sensitivity. Furthermore, this character's perceived subjugation of in-game creatures evoked thoughts related to colonialism and subsequent appropriation of resources by colonial powers. Based on early feedback from a variety of stakeholders, subsequent iterations of the game successfully eliminated in-game elements that evoked such stereotypes and had negative connotations. Later iterations also sought to further refine the avatar—given that testing revealed a greater desire among players for an avatar with whom they could empathize.

FINDINGS: SECTION ONE

REFLECTIONS ON THE DESIGN BASED RESEARCH PROCESS

THE TEAM

The assembled team was highly skilled and structured such that members had complementary roles. There was consensus among DBR team members and other stakeholders that the team assembled to advise, design, and develop the game was highly skilled in a variety of areas—including subject area expertise, design expertise, instructional expertise, and youth/educational research expertise. In the end, one DBR team member felt that "being able to collaborate with all the different teams and pull together information made for a stronger product." Furthermore, there seemed to be a good fit among the various team members including their interests, strengths, and their roles within the project. Over the lifetime of the project, team members came to have a clearer sense of their roles within the project—resulting in effective divisions of labor.

Prior collaborative experiences proved beneficial. Many of the team members contributing to the development of *The Pack* game, had had prior collaborative experiences and those experiences seemed to have a positive impact on the resulting success of this project. Before coming together to work on the development of this new game, several team members previously worked together on the development of the *Connected Worlds* interactive exhibit installation at the New York Hall of Science. They were therefore able to build upon previously existing relationships rather than having to start from scratch. Also, because of their prior collaborative experiences, these team members seemed to have a better understanding of the design process, various team members' roles, and mutual trust and respect for one another. As such, team members knew and understood their role in the design process and trusted everyone to do what they'd been assigned to do.

Team members shared a collaborative spirit and felt the DBR process was successful in fostering a sense of collective ownership in the game. The DBR process succeeded in fostering a sense of collective ownership of the resulting game. Stakeholders found the iterative design process to be largely transparent, and appreciated the fact that input was sought from a variety of experts and project stakeholders. Advisors were happy to provide information, clarify concepts, share examples, identify relevant research, correct misconceptions, and discuss different design concepts thoroughly. Rather than claiming ideas as their own, team members and contributors came to experience a sense of collective ownership as they shared and discussed ideas that evolved over time. For example, one advisor explained, "I don't know that I've seen specific things and can say 'this is my idea' but I do see that ideas that I might have uttered at one point have been incorporated into other ideas or other ideas have been included within those ideas." Ultimately, this collaborative team spirit contributed to an open and non-judgmental work environment, which in turn, fostered creativity, effective iteration, and a general sense of optimism about the game as it evolved.

Team members felt there was ample communication and effective management. Team members felt that the project was well-managed—especially in terms of the flow of information at different stages of the design process. Just enough information was being shared with the right people, at the right times. Team members indicated that project managers were also good at getting other stakeholders to step back and critically reflect on the project at key stages during the design process. These management practices helped keep things on track, while providing enough flexibility for design team members to approach the assigned tasks in ways that worked best for them. "It helps to have a really strong leader, capable of translating inputs from a variety of stakeholders into clear and actionable items and next steps," explained one DBR team member, "someone who can translate the goals of the team, keep everyone on task, and manage meetings."

Challenges of DBR Process and Solutions

In addition to the strengths of the DBR process described above, there have also been a limited number of challenges identified by stakeholders. The most frequently cited challenges were the need for additional time to conduct research and communicate findings to the team, as well as changes in the composition of the team over time. These challenges and subsequent solutions are discussed below.

Team members discovered that the DBR process takes more time than development processes with less emphasis on iterative research. Project stakeholders found that the DBR process required additional time to enable product testing at each stage of the design process. "It doesn't work as quickly as I would like," noted one DBR team member, "it's not realistic to have fast turnarounds…it takes longer, but you have a better understanding of the product and support for users." Another team member highlighted the fact that "developers have to wait to get feedback…but they appreciate having the feedback to change the direction or improve the product."

> *"Developers have to wait to get feedback..but they appreciate having the feedback to change the direction or improve the product."*

The timing challenge was exacerbated, to some extent, because of the added challenge of recruiting youth in the target age-range (i.e., middle-schoolers) to participate in game research sessions at the museum. However, the research process eventually became more efficient, and slightly more time was built into the schedule to facilitate formative feedback.

Team member turnover is natural but can be disruptive. Over the lifetime of the project, a handful of team members left to take on new jobs or new positions that necessitated their departure from the team. With the departure of team members, those remaining noted the challenges associated with bringing new team members up to speed. Team members found that keeping track of research findings, documenting key design decisions, and ensuring open communication with new team members aided the on-boarding process for new team members.

Asking for feedback from the wrong people or at the wrong time could be counterproductive. Not surprisingly, DBR team members found that asking for feedback from the wrong people at the wrong times was less productive than asking for feedback from the right people at the right times. Over the course of their involvement with the project, DBR team members came to realize that they needed to get to a certain stage, design-wise, before seeking expert feedback. Unfiltered input from scientific experts mid-way through the project resulted in subsequent design iterations that were less appealing because they sought to represent the real world and real-world functions too literally. Ultimately, when it came to seeking and sharing expert input, DBR team members found that some filtering and interpretation was necessary "to help the designers stay focused on the core educational objectives." Team members also came to realize that it was more beneficial to work with teachers when there were playable iterations of the game, rather than interim prototypes that featured more isolated game-play components. One DBR team member noted that "it was important to learn that it has to be far enough along to get good feedback."

> *"It was important to learn that it has to be far enough along to get good feedback."*

Outcomes of DBR Process

By capitalizing on the strengths of the DBR process and overcoming challenges they encountered, the DBR team was able to realize the following successes.

The process produced an innovative and engaging game. The most notable outcome of the DBR process adopted as part of this project was the resulting game itself. In addition to being well-crafted and visually appealing, the game succeeds in addressing both computational thinking and environmental science concepts.

The resulting game appeals to a wide range of users and has potential application in multiple contexts. Being able to emphasize the needs of various end-users throughout the design process contributed to the development of a game that doesn't just appeal to one type of player or work in a single usage context. "It really gets to the heart of how children are playing the game," explained one member of the DBR team, "and it changes the game in response to how children use it—it feels like it's representing the audience. It's more than just theorizing how audiences will interact with it. Bringing in the audience informs the design to help then better serve the audience."

> *"It feels like it's representing the audience…Bringing in the audience informs the design to help then better serve the audience."*

The process also helped to ensure that the game appealed to certain groups of users. A member of the DBR team explained that the "process has helped to take the perspective of underrepresented audiences (girls, minorities)…helping them engage with the game, rather than just hoping it will appeal to them. It incorporates their interests."

Over the lifetime of the project, the game evolved in meaningful ways. In addition to being well-crafted and visually appealing, each iteration of the game sought to meaningfully foster computational and systems thinking experiences in addition to related environmental concepts. The

FINDINGS: SECTION ONE

REFLECTIONS ON THE DESIGN BASED RESEARCH PROCESS

team initially sought to balance these concepts, but then began focusing more effort on environmental science concepts, However, in the final year of the project, there was a strategic decision made on the part of key DBR team stakeholders to revert back to ideas and concepts from earlier iterations that focused more on computational thinking. "We started the project with a specific design idea: to focus on computational thinking and environmental science equally, but that didn't really work," explained one DBR team member. "The DBR process helped the team think through and hone in on the ideal content and purpose. We wouldn't have gotten there without going through the DBR process."

"The DBR process helped the team think through and hone in on the ideal content and purpose. We wouldn't have gotten there without going through the DBR process."

Being exposed to the DBR process led team members to place greater value on iterative testing. Over the course of their participation in this project, some DBR team members gained additional research skills, while others came to see the benefits and therefore placed greater value on iterative testing. As evidence of the success of the process, one DBR team member cited the value of testing, stating that "it feels like a big victory to be discussing how to fine-tune the game and make it even better – not just about 'does it even work.'" Interviews with DBR team members suggest that this experience will therefore have a great and ongoing impact on subsequent design efforts undertaken at the museum.

The image above is a screen shot from the final version of "The Pack" game, developed during the NSF-funded grant period.

FINDINGS: SECTION TWO

THE GAME

Introduction

A second focus of the external evaluation effort was tracking specific issues and challenges related to the game, the subsequent recommendations that emerged in response to those challenges, and the resulting impact that these elements had on the resulting game. At the end of the first year, DBR team members had identified five key challenges that they then sought to address during the later half of the design process:

1. Striking the right balance between Computational Thinking and Environmental Science
2. Narrowing the content focus
3. Determining whether the primary focus would be in-school or out-of-school use
4. Balancing the need for structure/set objectives with desire for open-ended play experience
5. Striking the right balance between real and fictional aspects

In the later part of the grant, DBR team members worked to resolve these challenges in order to facilitate development of a functional prototype. Each challenge is discussed in greater detail below.

Challenge One: Computational Thinking vs. Environmental Science

DBR team members sought to create a game that addressed both computational thinking and environmental science. While it was certainly possible to include elements of both, they came to the realization that it was necessary to clarify their primary objective (i.e., were they seeking to create an Environmental Science game that incorporates concepts and strategies associated with Computational Thinking as topics and gameplay mechanics, or a Computational Thinking game situated within an Environmental Science theme?). Over the course of the project's first year, there was much discussion and eventually many ideas generated about how these two subjects could overlap and dovetail with one another. At the midway point of the design process, the team shifted greater attention to environmental science concepts, but gradually, there came to be a clearer sense among stakeholders that the game should make use of computational thinking strategies—and other processes related to computer science such as algorithmic thinking—in order to better understand environmental science and to solve environmental science problems. DBR team members came to agreement that the game would seek to foster skills and "habits of mind" that computer scientists use to solve problems.

The resulting product of this grant period is a game that succeeds in requiring players to employ computational thinking strategies to explore a virtual world—amassing a pack of creatures to aid in their exploration and making use of the pack to help find and retrieve seeds that collectively modify the environment over time. Players are faced with the challenge of not being able to venture too far from water sources within the game—i.e., an effective constraint to their ability to move around the world without problem solving efforts. Likewise, each creature that a player adopts into their pack requires a certain kind of food, and food is subsequently required if a player wishes to use a creature as part of a algorithm to accomplish a task within the game. There is also some evidence to suggest that game players are able to identify environmental challenges within the game world and that they come to realize that computational thinking skills can be applied to solve them.

FINDINGS: SECTION TWO

THE GAME

Challenge Two: Narrowing the Focus

Over the course of the first year, various stakeholders involved in the design of the game worked to generate a large set of possible learning outcomes for the game—including potential learning objectives within environmental science as well as potential learning objectives related to computational thinking. The resulting challenge that subsequently emerged was a need to narrow the list of possible topics down to a more manageable set of concepts that the game could realistically cover. In order to effectively narrow the list down, the team sought to:

- identify concepts and topics where there was a natural fit between environmental science and computational thinking;
- steer clear of topics/concepts that teachers already have effective ways of teaching and, instead, focus on topics that have posed instructional challenges for teachers—i.e., those that students have struggled to learn through current pedagogical practices; and,
- identify subsequent topics that could be effectively covered and conveyed within the game.

Over the course of the projects' first year, team members explored several areas where there were meaningful overlaps between environmental science and computational thinking. Despite coming up with several options for topics that the game could potentially address, team leaders kept the group focused on the need to hone in on a more modest set of topics and skills rather than trying to cover an entire environmental science and computational thinking curriculum. As one of the team leaders explained, "The content we are going after is so complex and so layered. We need to pick one or two concepts to develop and leave the others behind—if you can teach two out of six important concepts, you've done pretty well." After narrowing down the list of target concepts, DBR team members then used the information they gathered from teachers in order to better understand which topics might be a good fit for middle school-aged youth based on the topics typically covered in those grade levels.

The resulting game focuses players on a series of seemingly simple tasks (i.e., exploring the world and finding seeds) that are inclusive of inherent challenges, such as the need to stay near water, the need to find the right foods to acquire and utilize new creatures, and the need to dig down or build up to reach seeds in higher levels of the game. To address these in-game challenges, players must create algorithms. Given the complexity of the task they are seeking to perform, players may get by with a more simple algorithm that consists of only one or two steps, or they may be required to develop multiple algorithms or create a more complex algorithm. Either way, players are forced to break complex tasks up into smaller steps and determine the correct order for each operation. They must also work within the constraints of available resources (i.e., the creatures within their pack at any given period of time, and/or the available food resources they have collected to feed each creature within their pack. Players must think strategically in order to solve problems, they must address inherent tradeoffs, and can ultimately elect to incorporate repetitive processes to make their in-game algorithms more effective and efficient.

Challenge Three: In-School vs. Out-of-School Use

Throughout the design process, there was significant discussion and some debate about the primary usage context(s) of the game. Members of the DBR team were tasked with determining whether this was a game being designed primarily for use by children outside of formal learning environments (i.e. a game that is fun enough that children will seek to play it on their own) or something that was primarily designed to be used in school—with the support of educators who can help to scaffold gameplay and related learning experiences. Designers and DBR team members ultimately reached a consensus that the game had to be appealing as a stand-alone product first and foremost, but arguably one whose educational potential could be enhanced in instances where gameplay experiences were directed and supported by knowledgeable facilitators. Even though team members were ultimately committed to designing a game that was capable of standing-alone, they continued working with educators to seek feedback about how the game might be used to foster in-school learning experiences. Likewise, the team is planning to facilitate more extensive curriculum development efforts in the future.

DBR Team members were united in a belief that the resulting game likely couldn't be everything to everyone in every setting. There was consensus that the game should be fun, first and foremost, and at its core, it should be a game that people want to play. Nonetheless, team members also felt that it should lend itself well and easily to use in schools—whether through in-game instructional elements that don't detract from the fun, or with external resources and curricula that help facilitate more meaningful educational experiences in classroom settings. In sum, they sought to develop a fun and functional game that youth would want to play and teachers would see value in using as well. Therefore, at the heart of this challenge was the subsequent need to strike the right balance between the educational value of the game and the general sense of "fun" that youth have while playing it.

Considerations for Out-of-School Use

Focus on aspects of computational thinking perceived to be fun. Solving problems can be hard work, but youth often enjoy the experience of successfully solving a problem. Therefore, team members suggested that the game focus on the problem-solving aspects of computational thinking that are more likely to be perceived by players as "fun" rather than specific coding skills that may feel more like "work."

Get the difficultly level right. A successful game must strike the right balance in terms of difficulty. It can't be so difficult that it becomes hard for players to make sense of their game play experience —but it can't be so easy that players are just scratching the surface. It is okay for players to wrestle with concepts a little, so long as they are ultimately successful in their efforts to draw correct conclusions and come to a better understanding of core concepts.

Considerations for Use in School

Despite the primary desire to make this a game with educational value outside of formal educational usage contexts, there was nonetheless a desire on the part of the development team to ensure that

that resulting product could be used effectively in classroom settings. The following issues related to in-school use were identified by project stakeholders, including members of the teacher workgroup.

There may not be perfect alignment between the game and middle school teachers' curriculum. Computational thinking is not something that middle school teachers are typically familiar with, nor are they typically required to teach computational thinking. Nonetheless, members of the DBR team sought to help teachers come to see the value of proactively addressing computational thinking in ways that are grade-appropriate. The DBR team members also didn't seek to cover all topics included in the middle school Environmental Science curriculum—opting instead to capitalize on concepts where there were natural overlaps between Environmental Science and Computational Thinking.

Teachers have set notions about what an educational game should be—and this game may deviate from those norms. Teachers were quick to point out key differences between early iterations of the game and other educational games they were familiar with—i.e., typically close-ended games with overt instructional objectives designed primarily for use in formal educational settings and games with structured levels that present challenges in ever-increasing levels of difficulty. Admittedly, the teachers who were involved in the design process thus far were less familiar with open-ended games and therefore less sure of how they might be able to incorporate such games into their instruction, however, in later stages of the design process, most were able to suggest several ways that the resulting game could be incorporated as an instructional resource.

Teachers may need help to ensure alignment with standards. For the aforementioned reasons—i.e., the game being somewhat outside of traditional curriculum areas that middle school teachers have traditionally taught, and because they may not have had a great deal of experience implementing educational games, especially those that are more open-ended—DBR team members and teachers alike felt that it would be important to aid teachers in the development of lesson guides and other resources that could help educators align instructional use of the game with relevant academic standards.

Teachers may need extra resources and training to effectively implement the game as an instructional tool. Because they are less familiar with use of games that are open-ended, and because they may not have formal experience with computational thinking skills, additional resources and training experiences may be required to help bring teachers up to speed on how to use the game for instructional purposes. DBR team members suggested that it was unfair to assume that educators would play the game and simply understand everything they would need to know in order to effectively use it as an instructional tool. As such, it has been posited by members of the design team that teachers might need help structuring tasks and lessons effectively, and would also need resources to help them notice and make sense of what their students were doing in the game. Likewise, all game-design stakeholders agreed that discussion and reflection would be important pedagogical tools to help students discern meaning from gameplay experiences in schools, and as such, teachers may benefit from additional scaffolds that would help them foster meaningful discussion and reflection with students.

FINDINGS: SECTION TWO

THE GAME

After reviewing the final product in the late fall of 2018, teachers noted a need for additional instructional supports, including the following:

- **Teachers requested instructions on how to effectively introduce the game to students.** Teachers identified the need for guidance on how best to introduce the game—knowing that most students would prefer to dive in, but realizing that providing some instructions up front might help to facilitate a more productive educational experience. Likewise, teachers noted that some educators “may not be as comfortable letting their class go to figure it out...some teachers will want specific prompts to give their students, others will be more comfortable with ambiguity."

- **Finite instructional time would likely necessitate some constraints and/or supports to aid players with limited amounts of time.** They also sought input on how to constrain and support open-ended game-play experiences within a class period that has a finite amount of time (e.g., how to help ensure that students can progress at a reasonable pace and not get stuck). While they recognized the fact that a more open-ended game provides educators with more diverse usage options, teachers felt that some constraints and/or setting-controls would ultimately be necessary in order for successful in-school usage. As one teacher pointed out, it could be a problem “if it takes too long a time to do—to find certain characters or resources—it makes it more challenging to squeeze the experience into a class period.” Likewise, teachers noted that children will spend forever on an activity if they are allowed to do so, so it is necessary to “give them guidance; a framework for looking at their accomplishments.”

- **Teachers sought guidance for how to facilitate use of the game with diverse groups of students.** Educators suspected that some students would be likely to work through the game at a quicker pace than others for various reasons; others might require more support. As one teacher noted: “Students with different skill levels will take different amounts of time and face different challenges.” For these reasons, teachers suggested that it would be helpful to build certain controls or scaffolds into the game and/or provide guidance for teachers on how best to use the game with students with different academic skills or gaming abilities.

- **To optimize learning outcomes, teachers acknowledged the importance of resources to aid in the post-play reflection process.** Because students often need help to unpack and make sense of what they have learned, teachers also suggested the need for a discussion guide or tips to help educators facilitate conversations with students that will help them connect the game play experience to desired educational outcomes. In her limited experiences exposing youth to the game, one teacher noted that her “students would say they didn’t learn anything in the game, but in conversation they would talk about things they did. So they didn’t know they were learning.” Teachers concurred that most youth were not likely to make connections between in-game learning and curricular objectives on their own, so it would be necessary for educators to facilitate reflection in order to ensure that desired connections are made and subsequent learning outcomes are fully realized.

Challenge Four: Open-Ended vs. Objective-Driven

Despite the general goal of creating an open-ended play experience, project stakeholders realized that they had to determine the extent to which readily identifiable goals and gameplay objectives were necessary in order to foster educational gameplay experiences that fostered players' sense of accomplishment. In other words, the DBR team members faced the challenge of striking a balance between structured and open-ended play, such that the resulting game was both an open-ended experience that also had sufficient objectives and in-game scaffolds to help ensure meaningful play, capable of producing desired learning outcomes. On the one hand, there was a desire for the resulting game to allow players to randomly explore—embracing a "let's see what happens" mentality. On the other hand, objectives were needed to hold player attention, drive player engagement over longer periods of time, and foster the types of exploration that were most likely to produce desired learning outcomes, e.g., scientific habits of mind that support questions like: "What will happen if I do this…or this?"

Open-ended games lend themselves to multiple solutions. There seemed to be a clear desire—prompted both by conditions in natural environments as well as computational thinking practices—to provide in-game problems that have multiple solutions, rather than single "correct" answers. At one point in the game design process, developers sought to enable players to establish balance within biomes. Due to the complexity of this type of task, there arguably wouldn't be one right way to go about it, but instead, a series of tradeoffs would be necessary to complete the task. DBR team members noted the fact that the dynamic and ever-changing nature of natural systems lend themselves to multiple solutions. Even though the team moved away from the concept of creating balance within biomes, the resulting game still supported the intent to make players consciously aware of the fact that there are often many different ways to solve problems. This concept—i.e., the fact that there is not always one correct solution—and the related fact that there may be multiple solutions, are important ideas for youth to grasp and could serve as gameplay objectives in and of themselves.

Open-ended games may be more challenging to implement in formal educational settings. As discussed earlier, members of the teacher workgroup voiced concern that open-ended games are often viewed by educators as being more challenging to implement. Though there has been increasing use of open-ended games like *Minecraft* in schools, most teachers still tend to gravitate toward drill and practice games or leveled instructional games because they make it easier for teachers to know what their students are learning or doing. Because classroom teachers must ensure their students are covering specific skills and content, an instructional tool wherein the path to learning specific outcomes might take a more circuitous path can make it harder for teachers to account for students' learning along the way. Educators must find ways to keep students from getting off task and they must also find ways to make sure that all students can accomplish the desired curricular objectives within the timeframe that has been set aside for instructional activity. In working with the teachers who were part of the teacher workgroup, DBR team members came to realize a general need to advance teachers' awareness of the educational potential of open-ended games and better understand how to use them effectively. Team members have also recognized the underlying importance of creating enough structure to keep players from getting lost or becoming confused because they don't know where to go or how to proceed within the game.

Challenge Five: Fictional vs. Real

The final challenge that emerged over the course of this project was determining the extent to which the game should be reflective and representative of how things actually are in the real world or, conversely, the extent to which the game should present fictional environments and characters. Members of the DBR team debated the correct mix of in-game features and experiences that mirrored those found in the real world, in contrast to artificial elements which were strategically designed to foster desired learning outcomes. On the one hand, greater similarities were seen as a way to help foster transfer of in-game learning to players' understanding of how things work in the real world. However, due to the inherent complexities of the way things are in the real world, there were fears among DBR team members that efforts to more closely adhere to the way things are in the real world might make the game too difficult to play and understand. For example in one iteration of the game, team members sought to establish the right balance of the types of randomness that were inherent in nature, while also seeking to make the game predictable enough to support purposeful play. They also sought to strike the right balance of real-world and fictional components so as to prevent players from developing misconceptions about the way things are in the real world.

The Strengths of a Realistic Approach

Players can bring prior knowledge to bear on the gameplay experience. An in-game experience that more closely mirrors how things are in the real world enables players to apply what they already know about the real world. Rather than making random assumptions about what might happen if they try things, players can make more educated guesses. Being able to build upon the knowledge and experience that players already have may also mean that they can be more successful more quickly within the game.

The closer things are to reality, the easier it may be for knowledge and skills to be transferred to real world situations. Members of the DBR team sought to ensure that players were able to make connections between what they were learning or discovering in the game with concepts and skills that are applicable to the real-world. Some argued that the more similar the game was to the real world, the more easily players could accurately extrapolate what they had learned. In other words, an in-game world more closely related to the real world, means players wouldn't have to work quite so hard to come away with an accurate understanding of real-world concepts.

The Strengths of a Fictional Approach

The real world is random and complex. Reality is complex. Some advisors argued that modeling things in the game more closely on how they are in the real world meant making things comparably complex. In the real world, the behavior of creatures and environments aren't always predictable. They are the result of complex interrelationships and interactions as well as some inherent randomness and chance. DBR team members, however, were mixed in their opinions about whether complexity and randomness were necessary in order to give an accurate representation of the world or could instead be factors that would make concepts more challenging for players to grasp. On the other hand, designers worried that the complete absence of complexity or chance might arguably make things too predictable and could cause players to lose interest in the game over time. As such, there might be advantages to a fictional game world wherein complexities can be scaled-back and controlled and randomness and chance can be moderated in order to optimize the gameplay experience. Deviating a little from reality, in other words, might be necessary in order to keep things manageable and fun.

Fictional environments and characters may help players avoid misconceptions that could come along with prior knowledge of the real-world. While there may be advantages to prior knowledge that players have about the real world—as noted above—there is always the potential that players' understanding of real-world phenomena may be partially or wholly incorrect. Therefore, rather than starting from scratch to figure out how things work in a fictional game world, prior knowledge may present an obstacle or stumbling block for player success.

A more fictional approach would help to level the playing field for all players. When there is greater use of fictional elements within a game, it is easier to ensure that all players start at the same place. Conversely, in instances where there is greater use of environments or characters borrowed from the real world, it is more likely that players will have different levels of prior knowledge.

Neutral Ground Between Fictional and Realistic

Teachers have cautioned that some learners are pre-disposed to process and internalize things in very literal ways. This can be problematic both in cases with in-game elements that are unlike the real world (e.g, thinking it is okay to walk up to any creature that you encounter in a new environment, or a good idea to try to lure animals to you with food)—but also problematic insofar as players may come to believe that all the creatures and environments they encounter in the game are real.

Fictional may be more of a pull than real (or vice versa). Some players are likely to be lured into a game-world that is entirely novel and full of new things to do and discover. Others, might be enticed by the ability to explore a world that is more closely related to their own. Teachers have also pointed out that many creatures and places in the real world seem just as fictional to students as things they encounter in games (e.g., rain forests and coral reefs), so arguably there is going to be a need for educators to help students discern between what is real and what is fictional, no matter the resulting in-game mix of real and fictional elements.

Broader Perspectives

Several DBR team members pointed out that the "fictional vs. real" debate took place during the design of the Connected Worlds exhibit as well. There is ultimately value in studying how both of these virtual worlds—both the game and the exhibit—can engage youth and foster a deeper understanding of embedded concepts. The resulting goal for designers and educators alike, then becomes finding ways to ensure that game players are able to effectively and accurately identify areas of overlap between the real world and the fictional world.

FINDINGS: SECTION TWO

THE GAME

The Resulting Game and Inherent Solutions

As part of the summative evaluation effort, the evaluation team sought to examine the resulting game and the inherent solutions to the aforementioned challenges:

- Challenge One: Computational Thinking vs. Environmental Science
- Challenge Two: Narrowing the Focus
- Challenge Three: In-School vs. Out-of-School Use
- Challenge Four: Open-Ended vs. Objective-Driven
- Challenge Five: Fictional vs. Real

The DBR team successfully addressed the first two challenges by electing to return to earlier design concepts that focused more extensively on computational and algorithmic thinking, rather than seeking to address specific Environmental Science concepts more thoroughly. The earlier design concept—allowing players to collect creatures with different skills and employ them either individually or as part of stacked algorithms to accomplish specific tasks—proved more functional and capable of fostering engaging and meaningful gameplay outcomes. Despite focusing more on computational thinking elements, the resulting game product also proved capable of supporting deeper thought about environmental concepts such as responsible use of limited resources and systems thinking as well.

Feedback and input was gathered from teachers throughout the design process, however, DBR team members adhered to the belief that the game needed to function well on its own—without the support of teachers, and as such, shouldn't be designed in such a way as to be optimized for use in in-school settings. Teachers were generally supportive of the notion that an engaging game, based on computational thinking principles, could ultimately be incorporated for instructional purposes even if it was more open-ended than other kinds of games and digital resources they were most familiar with using. However, there was also a realization that not all teachers will be comfortable using such a game without more extensive supports and resources to scaffold its use within classroom settings.

The resulting game has specific objectives and a finite set of levels, however, players are able to go about accomplishing these objectives in myriad ways. As such, the game feels open-ended, even though sufficient constraints are provided to facilitate meaningful play and foster educational experiences. The game does not provide instructions beyond an initial tutorial that teaches players how to collect fruit and seeds, and in doing so, leaves players to discern the overarching objectives of gameplay. Most players rightfully deduce that the goal is to adopt creatures into their pack and find seeds by exploring the given landscape. Likewise, other than the digger, the game does not provide overt tutorials on how to use each creature, nor how to develop more complex algorithms. Some players have expressed a desire for more tutorial elements in order to support more purposeful use of in-game resources, however, some appreciate the challenge of being able to experiment to try to figure out what each creature can do—or might be able to do in combination with others.

Lastly, the game designers ultimately preferenced "fictional" over "real." However, while the creatures and plants are directly not modeled on real-world creatures, the virtual environment approximates that of the real world in ways that are sufficient to facilitate thought about real-world parallels with concepts such as resource management and scarcity.

FINDINGS: SECTION THREE

TEACHER PERSPECTIVE

Introduction

The summative evaluation sought to determine how teachers responded to the game, identify potential benefits and perceived barriers to student learning, and identify potential resources that might be necessary to overcome these barriers. This section of the report seeks to address teacher-related findings in great detail.

Teacher Contributors

Teachers were incorporated in the design process through the NSF-funded grant period. An initial teacher workgroup was convened to provide feedback at key points during the project's first year. The majority of members of this group opted to stay on for the remainder of the grant, and additional educators were invited to participate. The evaluation team conducted observations of workgroup sessions and conducted a series of focus groups with participants. Evaluative findings were also informed by data from focus group sessions with other ad hoc groups of teachers, such as those participating in professional development experiences at the museum.

Four teachers were a part of the first teacher workgroup. Those teachers were invited to meet face-to-face with select members of the DBR team at key points during the first phase of the design process. As part of their experience, they:

- helped members of the DBR team find examples of "hooks" in the Connected Worlds exhibit that could help inspire and inform ongoing game development efforts and help ensure that the resulting game is both engaging and educational for youth in the target age-range.
- identified areas where there may be common curricular objectives for environmental science and computational thinking.
- shared knowledge about the types of things students struggle to understand and identified topics that teachers need help with—in contrast to subjects that are easy to teach or that teachers already have good ways to cover.
- provided guidelines and recommendations to help ensure that the resulting game could effectively be incorporated for use within formal educational settings.
- shared insights and made recommendations on the types of things that could help children in the target age-range enjoy and benefit from playing on their own, outside of school.

Members of the DBR team rightfully assumed that some workgroup participants would want to stay involved past their initial contract period. "We knew it would be a disappointment…a disservice if they didn't get to see the final prototype," explained one member of the DBR team. Therefore, contracts were extended with teachers who wished to continue as the grant continued into a no-cost extension period and new teachers were invited to be a part of the workgroup in the projects' final year. This group ultimately included five teachers—a mix of those from private and public schools, both veteran and novice teachers, a mix of subject and grade-levels taught, and a mix of those who worked with

with students at a remedial level, some who worked with average students and some who worked with advanced students. Despite the diverse nature of their experiences, the sample of teachers that contributed feedback about the game is not wholly representative of all the diversity present in the teacher population at large—especially insofar as their openness to considering use of open-ended gaming experiences for educational purposes.

Workgroup Process

In the later half of 2018, four sessions were held with the new teacher workgroup: In the first session the teachers came together at the museum to pilot a new version of the game. Next, they assembled (online) for a discussion of their experiences playing the game "as learners." That session was followed by a third meeting (again online) wherein they were asked to evaluate and discuss the game from a teachers' perspective. Lastly, the team was challenged to play the game once again and consider it, and its potential, from a curriculum development perspective; they returned to the museum for this final face-to-face discussion. During each teacher workgroup session, DBR Team members reiterated that the teachers are the educational experts. When teachers asked questions about "the right way to use the game or do something within the game," the DBR team members were skilled and persistent at instead turning it around and asking the teachers for their thoughts and opinions.

Findings and Recommendations from Teacher Contributors

Teachers' Prior Knowledge and Experience

Teachers' familiarity with computational thinking is likely to be limited. The teachers were somewhat well-versed in curricular objectives for Environmental Science but, understandably, less so for computational thinking since it is not a subject they had previous experience teaching. Furthermore, exposure to computational thinking was not typically a part of teachers' personal educational experiences. With these two factors in mind, there were understandably misconceptions and incomplete notions about what computational thinking entailed. For example, some members of the initial teacher workgroup thought that computational thinking was merely mathematics—i.e., use of equations and calculations, however, over the course of their participation as part of the teacher workgroup, those teachers came to learn that there was much more involved in computational thinking. Teachers also came to see additional value in being a part of the teacher workgroup due to anticipated national, state and/or local efforts to infuse more computational thinking into the grade school curriculum.

Teachers have limited experiences using open-ended games as educational resources. Most teacher workgroup members found "The Pack" to be a different style of game than they were used to using and suggested that educators aren't as familiar with open-ended games as they are with more linear and more structured games. They have greater levels of familiarity with drill-and-practice and other types of linear games with progressively harder levels. As such, they suggested that use of an open-ended game would likely require a different instructional approach and therefore noted that some teachers would require more resources, support, and training to effectively incorporate the game as part of the instructional process. These teachers did, however, see potential benefits of using games—especially with certain populations of students including English Language Learners and special education students.

Teachers' Reactions to the Game and Observations of Student Outcomes

Teachers saw elements of the game that aligned with subjects that they teach. Teachers were readily able to identify elements of the game that related to the real world and specific topics that they teach. For example, multiple teachers commented on the potential to use the game as a means to address resource scarcity—as prompted by in-game experiences of needing a certain kind of food and not being able to find it easily. Others felt that the game provided opportunities to explore the idea of conservation (i.e., thinking about the consequences of using up all of a single kind of food and not having access to it in the future). Another teacher explained the game's relation to the concept of the "tragedy of the commons"—a concept taught in Environmental Science. For example, teachers saw the game as a way to explore the question: "If you take too much food, what's going to be left for someone else" and to help seed conversations about the ethical dilemma of over-harvesting a resource. Teachers also noted that some students were (or likely would be) conscious of what they were doing to the environment. "I would hope they'd see how their actual decisions impact the real world," explained one teacher. Another teacher workgroup member recounted an instance where a student's diggers had all died and the student felt bad. It was clear in this instance that the student "felt their actions were impacting this virtual world." Teachers noted other in-game instances where their actions were changing the world—for example if a player digs trenches or carries water, it changes the surrounding landscape. Teachers felt gameplay examples such as these could foster thinking about real-world consequences of their actions. Teachers also cited elements of pattern recognition (e.g., the fact that food is always close to water) that could be explored through the game. And lastly, in the limited instances where teachers were able to invite actual students to informally try out the game, they noticed that students were having discussions with their peers on how to solve different challenges.

Teachers' Recommendations

Scaffolds may be necessary to support meaningful use of the game for educational purposes. Teachers noted that scaffolds may be needed to help support players' discovery of in-game relationships and outcomes based on different inputs. Whether they are ultimately included within the game, or are provided outside of the game, teachers felt that additional resources would likely be necessary to help players observe, keep track of, and make sense of things that are happening with the game. For example, observation reporting templates may be necessary to prompt players to note things that they see over time or within different regions of the virtual world. Prompts may also be necessary to help players make effective use of in-game controls, e.g. the ability to speed up or slow down the passage of time.

There are many logistical considerations for educators looking to incorporate games as educational resources. Implementation logistics are likely to vary from school to school and classroom to classroom. Some schools require all teachers to stay on the same schedule, whereas

FINDINGS: SECTION THREE

TEACHER PERSPECTIVE

other schools provide teachers with more flexibility and control. Access to technology and/or the internet also varies from school to school and cannot be taken for granted in all formal educational settings. Beyond scheduling and accessibility issues, teachers also emphasized the importance of being able to communicate to parents and administrators about why games are being used as an instructional resource rather than traditional modes of instruction. A member of one teacher workgroup pointed out that administrators will likely want assurances that the game-based learning experience will yield desired outcomes and may subsequently seek information on the specific standards being covered in a game-based instructional modules.

Another key logistical challenge of gameplay in schools is the amount of time it can take for students to complete gaming experiences. Teachers initially felt that allotting enough time for all students to get through an entire game could be a challenge and after playing "The Pack," their assumptions were confirmed. They reiterated concerns that some students would likely need more time to complete the game, or at least have all of the desired experiences and/or access all of the desired information. Being able to ensure that the gameplay experience accomplishes the intended curricular goals during the allotted time could therefore be a potential challenge that educators would have to overcome in order to be able to use it successfully as an educational resource.

Teachers recommended and applauded the team's efforts to ensure flexibility in terms of different ways the game can be played. Ultimately, some teachers and students may prefer a more goal-oriented gameplay experience, in contrast to a more open-ended gameplay experience. Providing players with options and features that allow different aspects of the gameplay experience to be controlled could ultimately help to ensure that the game lends itself well to different instructional uses. Likewise, giving educators the ability to tweak different settings within the game may enable to them to better customize gameplay experiences for different students or different instructional contexts.

Teachers' Participation in the Design Process

The teacher workgroup members were interested in seeing various iterations of the game and hearing about outcomes from play-testing sessions with youth. Overall, educators' participation in the design process seemed to be a novel and positive experience and produced valuable insights and feedback for the DBR team.

In the image on the left, three teens are shown playing "The Pack" during a play-testing session. Findings from youth play-testing sessions are presented in the following section of the report.

FINDINGS: SECTION FOUR

YOUTH PERSPECTIVE

Introduction

The summative evaluation sought to assess the extent to which the game is helping youth develop and apply computational and systems thinking skills. Beyond seeking out evidence of relevant impacts, the evaluation team was also charged with identifying specific strengths of the game as well as additional ways to strengthen its impact.

Youth Participants and Research Methodologies

Feedback on the game from youth came in three forms:

1. DBR team member research with youth at the museum and during the USA Science and Engineering Festival at Lockheed Martin site in DC where the game was featured as part of an NSF Booth in the spring of 2018.
2. Teacher workgroup members' observation of gameplay with their own students or children as reported during workgroup sessions and teacher focus groups throughout the project.
3. Play-testing sessions conducted by members of the external evaluation team.

In the case of the later, thirty-minute play-testing sessions were conducted with 14 youth between the ages of 10 and 14 (grades 5-8) over a three-day period. As they played "The Pack" on a Mac laptop, youth participants were encouraged to think-aloud (i.e., to share what they were thinking and trying to do as they worked through the game). A researcher observed each session and asked additional questions during play and immediately following play to gauge participant interest, engagement and understanding. See Appendix 3 for a copy of the play-testing protocol.

Findings and Recommendations from Youth Contributors

The game appealed to youth. The final version of the game created as part of the NSF-funded initiative was successful in holding the attention of youth—oftentimes upwards of thirty minutes. Evaluators also noted that it was sometimes difficult to get players to stop playing at the end of play-testing sessions which is generally a good indicator of a game's appeal. Teachers noted that longer play seemed to foster greater levels of investment and a stronger desire to collect all the creatures and figure out what they can do, and this finding was substantiated during play-testing sessions as well. Youth in the target age range specifically liked the look and feel of the game and they liked the ability to explore the world and to collect creatures.

Youth typically understood the objectives and most of its mechanics. In the external evaluation team's play-testing sessions, most participants seemed to grasp the general concept of the game (i.e., exploring the landscape, collecting creatures, and locating and collecting seeds), and were generally successful in their efforts to accomplish those objectives. There were a few instances, however, where participants needed additional input from the researchers to clarify or confirm gameplay objectives. A few additional recommendations were put forth in a more comprehensive report on the external evaluation teams' play-testing findings.

FINDINGS: SECTION FOUR

YOUTH PERSPECTIVE

Youth may need more prompting and scaffolds to produce more complex algorithms. Teachers noted that most of their students defaulted to using a single creature in an algorithm rather than combining them. The same trend was observed during play-testing sessions conducted by the external evaluation team. More help may be needed to scaffold player's exploration and use of more complex algorithms—and therefore more fully explore the underlying concepts of computational thinking that are present in the game. Some players requested additional tutorials or examples of how to use different creatures or combine them to perform different tasks. A few teachers concurred that additional tutorials would be helpful and may foster greater interest in and understanding of the game, however, one warned that by giving students examples, those examples might become the default solution.

There are some inherent challenges in the game, but overcoming them can be rewarding. Some players encountered problems finding seeds. This trend was observed it the evaluation team's play-testing sessions and teachers also reporting having seen this issue as well, as they allowed their students to play through the game. While youth desired hints, others thought it was rewarding to find the seeds on their own, and teachers thought this provided a unique opportunity for students to practice not giving up: "Students have to get out of the mindset that everything is instantaneous."

Modes of gameplay vary from child to child but most approach games with curiosity. Gameplay differences were noted by researchers within the DBR team based on children's gender. For example, in testing the second prototype, researchers found that girls and younger boys showed greater concern for taking care of the creatures in their packs. Researchers also found that some youth take a "trial and error" approach, whereas others are more strategic in how they approach gameplay. While most children intuitively explore, collect and experiment, some seemed more driven by curiosity, whereas others seemed more driven by a desire to accomplish specific goals or bring about specific changes within the game world. Lastly, researchers noted differences between novice and veteran gamers. Specifically, among the later, researchers uncovered expectations based on prior game-play experiences—for example, youth who had played *Minecraft* feared that they might come under attack at night.

Children seek out challenges and find innovative ways to compete. During their play-testing sessions with youth, DBR research team members noted that children often came up with objectives or ways to challenge themselves when overt challenges were not present in the game itself or articulated by the researcher conducting the play-test. Some youth specifically mentioned a desire for there to be more challenges and competitive elements. In the absence of a explicit challenges, some players sought to create their own—such as collecting as many creatures as possible or collecting one of each kind. Likewise, teachers asserted that students usually find ways to be competitive, even if that's not the objective. For example, if one student finds a way to gather creatures or food faster, others will seek to do it even more quickly, one teacher explained.

Making distinctions and connections between the real world and game world. Children identify and care about distinctions between the real world and the fictional game world to varying degrees. Members of the DBR team found that some youth where more inclined to call upon their prior knowledge and understanding of the real world to make assumptions or predictions during gameplay (i.e., what the research team has termed an "analogical approach"), whereas others were more included to reference in-game cues such as the way that different creatures and environmental elements looked (i.e., a "visual approach").

APPENDIX 1

STAKEHOLDER INTERVIEW PROTOCOLS

Round One: Early Gameplay Testing and Prototypes

1. Tell me about the role you've played in the DBR process thus far.
2. Has your role been/are your objectives clear?
3. How has your role/have your objectives evolved?
4. What, if any, challenges have you or others experienced thus far in terms of the DBR process?
5. To what extent has the DBR team been able to incorporate suggestions and ideas from participants with a variety of different backgrounds?
6. Moving forward, what are some of the key gameplay issues or consideration the DBR team will be seeking to address?
7. At this stage, how would you define success for the project? How will the team know when its been successful?
8. Do you have any recommendations or suggestions to improve the DBR process or resources that have been created so far?

Round Two: First Prototype

PROCESS QUESTIONS

1. Since we last spoke, how has your role/have your objectives evolved?
2. What, if any, challenges have you or others experienced thus far in terms of the DBR process?
3. What have been the greatest strengths of the DBR process thus far?
4. Did the DBR team have any key breakthroughs over the course of the past few months?
5. To what extent has the DBR team been able to incorporate <u>your</u> suggestions and ideas as well as those of <u>other</u> participants with a variety of different backgrounds?

PRODUCT QUESTIONS

1. Now let's talk about the prototype that the DBR team has produced…
2. What are the strengths of the current version of the prototype?

3. What changes have been made/what were the key iterations the DBR team has made in the past few months?
4. Are there any challenges with the current prototype that the DBR team is seeking to address in the coming months?
5. How do you plan to help address those challenges? Do you have any specific recommendations?
6. Do you have any recommendations or suggestions to improve the DBR process or products that have been created so far?

Round Three: Concept and Mechanics

PROCESS QUESTIONS

1. Since we last spoke, how has your role/have your objectives evolved?
2. Have you, or others, experienced any challenges in terms of the DBR process?
3. What have been the greatest strengths of the DBR process thus far?
4. Did the DBR team have any key breakthroughs over the course of the past few months?
5. To what extent has the DBR team been able to incorporate <u>your</u> suggestions and ideas as well as those of <u>other</u> participants with a variety of different backgrounds?

PRODUCT QUESTIONS: Concept and Mechanics

1. What are the strengths of the current version of the prototype?
    a. ...in terms of the concepts being presented?
    b. ….in terms of the game's mechanics?
2. Are there any challenges with the current prototype that the DBR team is seeking to address in the coming months?
    a. …in terms of identifying/addressing concepts?
    b. …in terms of the game's mechanics?

3. Do you have any recommendations or suggestions to improve the DBR process or products that have been created so far?

Round Four: Alpha Version and Testing Process

1. How has your understanding of the DBR process evolved over the course of this project?
2. Based on your experiences, what are the greatest strengths of the DBR process?
3. Based on your experiences, what are the challenges associated with the DBR process?
4. To what extent did the DBR process help to enhance the value of the resulting product?
5. Do you feel that the DBR process has been effective?
6. What are the greatest successes of your team thus far? What specific evidence of success can you identify?

Rounds Five & Six: Beta Versions and Testing Process

PROCESS QUESTIONS:

1. What is your role in the CTE project?
2. Has your role or your objectives evolved since you started?
3. Have you, or others, experienced any challenges in terms of the DBR process?
4. What have been the greatest strengths of the DBR process thus far?
5. Did the DBR team have any key breakthroughs over the course of the past few months?
6. To what extent has the DBR team been able to incorporate your suggestions and ideas as well as those of other participants with a variety of different backgrounds?

PRODUCT QUESTIONS:

1. What were the strengths of the most recent version of the prototype?

a. ...in terms of the concepts being presented?
b.
c. ….in terms of the game's mechanics?

2. What were the challenges with the most recent prototype?

   a. …in terms of identifying/addressing concepts?

   b. …in terms of the game's mechanics?

3. What is your understanding of the next steps that the DBR team will be taking?

   a. …in terms of the next iteration of the game?

   b. …in terms of testing concepts or prototypes with students and educators?

4. Do you have any recommendations or suggestions to improve the DBR process or products that have been created so far?

APPENDIX 2

EDUCATOR FOCUS GROUP PROTOCOL

Introduction

Thank you for agreeing to participate in today's focus group. I'm interested in hearing from everyone, but I may not have time to call on every person to answer every question. Please keep in mind that there are no right or wrong answers - I'm really just interested in learning what you think. If you have a response that is different from others that are shared, please speak up. I apologize in advance if I have to cut anyone off in order to keep us on track. Do you have any questions before we get started?

Questions about the DBR Process

1. To what extent has the DBR team been able to incorporate suggestions and ideas from participants with a variety of different backgrounds?
2. To what extent did you feel like your input to the DBR process was helpful? Valued?
3. Was your role in the DBR process clear? To what extent did it evolve over time?
4. Do you have any recommendations or suggestions to improve the DBR process in the future – especially any suggestions that relate to efforts to include educators as part of the DBR process?

Questions about the Game

1. From your perspective as an educator, what are the greatest strengths of the game?
2. Would you—or do you plan to—use the game in your classroom/with your students?
3. How might you go about incorporating the game as part of your classroom instruction?
4. Are there any potential obstacles to its adoption and use by other educators?
5. Is there anything more that can be done to help scaffold teachers' use of the game as an instructional resource?

APPENDIX 3

GAME PLAY-TESTING PROTOCOL

INTRODUCTION

- This game is currently under development, so some things may not be completely finished
- Think-out loud as you play + I might ask you some questions about what you are thinking/doing
- There are no wrong answers or bad ideas
- We'll play for about 20 minutes, then I have some follow-up questions

OBSERVATION QUESTIONS

The following are questions intended for observers, to get at what players are thinking/understanding at different stages of game play:

1. What impressions does the player form about the goals/objectives of gameplay at various stages?
2. What personal goals does the player adopt for him or herself as s/he plays?
3. What strategies does the player adopt for solving different problems (e.g., exploring, pack-formation and algorithm creation)?
4. What perception does the player seem to have have of of how successful s/he is in completing perceived or self-selected goals?
5. Over the course of game-play, what is the players' level of engagement?
6. What does the player think the game is about (including possible parallels with the real-world)?

FOLLOW UP QUESTIONS

1. What was your overall impression of this game? Was it interesting/fun? Was it similar to or dissimilar to other games you've played/like to play?
2. If we had more time, would you like to keep playing? (or play again in the future)?
3. What were you doing in this game? What do you think this game was about? If a friend ask, what you tell them about this game/what this game was about?
4. Did you like this game?/what did you like about the game?
5. Did this feel like a game for kids like you? Kids your age/Kids who like to play the same kinds of games as you?
6. Was there anything you didn't like about the game?
7. What did you learn or discover as you were playing?
8. Did the game remind you about anything you've learned at school?
9. Is there anything you would change or add to make this game more interesting or fun?