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# SCAMP: An Analytical Framework for Examining Flexible Social Playfulness Around Interactive Museum Exhibits

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## ABSTRACT

In this paper, we present SCAMP – Social Configuration Affordances for Museum Play – an analytical framework we develop and use to highlight the relationship between designed affordances at interactive museum exhibits and different social playful behaviors they trigger and support. We do this through a selective case study analysis of Rainbow Agents, an interactive museum exhibit designed to support play across multiple *social configurations*. This variety of configurations is valuable for museum settings, as it helps museum visitors engage with each other according to their preferences and also enables the emergence of modes of collaboration and competition novel for learners in such contexts. Our SCAMP analysis of Rainbow Agents sheds light on design features which successfully support different forms of productive social play – including short and long episodes of competitive, collaborative and parallel play, spanning play, teaching, and receiving interpersonal interactions. In particular, we pay attention to behaviors representing a variety of mentoring and learning opportunities – in line with and extending the vision and goals of educational games' and science museum exhibits' designers and researchers.

**Keywords**: Collaboration, Museums, Games, Design, Analysis, Conjecture Mapping

## 1.0 Introduction

There is a need to identify an expansive variety of collaborative behaviors across different learning contexts. This expansion is not only critical for better recognition of different styles of engagement but also, relatedly, for sensemaking processes that different social configurations enable (Zimmerman et al., 2010). As interactive technology is integrated into learning environments to support more flexible participation for learners, there is growing interest and work in understanding how space and interfaces mediate access to information, understanding, and participation.

For this reason, we designed an interactive museum exhibit (*Rainbow Agents*) designed, in part, to support creative computer science learning across multiple social configurations. Our core research question for this paper is: *How can we better understand the relationship between the design of such technological multi-interface exhibits and the social configurations they support?*

## 2.0 Background – Learning Socially at Multi-user Science Museum Exhibits

Our work builds on work from theories and prior work across learning sciences, computer science, and museum studies. That said, our contribution is best framed at the intersection of research on collaboration in the learning sciences and the design of creative STEM museum exhibits. Critically, we focus in-person museum exhibits, and our usage of interactive and digital refer to technological and computational interactivity in museum exhibits, almost never enabling long distance interaction.

This paper builds directly on previous work regarding social configurations (Enyedy, 2003; Roth, et al., 1999) which posits that physical space enables different roles and configurations. This groundwork is expanded through our use of Halverson et al.'s emergent forms of collaboration (Halverson, 2018) in open ended tinkering spaces, which shows how the design of a space towards "free flowing work" supports collaboration "through the air." Lyons et al. (2015) further suggest that the "visibility" of an exhibit – making visitors' participation and work easily seen, watched, and accessed – can enable those forms of collaboration in a museum space.

There is a significant body of work on social scaffolding in museums designed for family members. Gutwill and Allen (2010), in particular, suggests that the social configurations of family members may be more fruitfully flexible than previously assumed.

Hornecker et al. (2007) point to the opportunities that museums support for richer learning through shared participation, while Allen and Gutwill (2004) warn of the volume of challenges in designing for open-ended multiple user participation. Examples of these include: turn-taking, as a lack of input can lead to interference (Marshall, et al., 2009); the organization of access points may guide players/visitors into specific collaborations in unintended ways (Antle, et al., 2013); and multiple inputs may lead to parallel play while avoiding collaboration (Inkpen, et al., 1999). Most recently, Clarke et al. (2021) present four design factors in multi-user museum exhibits – namely, functional, temporal, physical, and secondary indirect verbal distribution of control – that can trigger different visitor behaviors like alternating sequential actions and relying upon companions and opportunities to support each other.

This leads to a frequent inherent tension present in multi-user exhibits between the value other visitors can provide via their performances – which often serve as exemplars or useful provocations (Meisner, et al., 2007) – and the ways in which other visitors' actions serve to constrain or outright inhibit what an individual visitor can do or explore (Lyons, 2009). This suggests that exhibit design needs to allow for a flexible range of social configuration (Lyons et al., 2014). Not all visitors desire the same degree or type of social engagement, and even the same visitor can desire a different degree or type of social engagement from one moment to the next, which makes social exhibit design difficult. Interactive technologies – specifically those with multiple interfaces – offer the potential for supporting more flexible face-to-face social engagement (Sugimoto, et al., 2004). But the solution is more than just a matter of supplying a multi-interface form-factor. We need to better understand how to design activities and feedback and distribute these across interfaces to support a wide range of human-human social configurations (for e.g., from parallel to competitive to collaborative).

We investigate this line of inquiry through the following research question around our museum exhibit: How can the design of technological exhibits support emergent collaboration in a museum space between different sets of people – families, strangers, friends – which will in turn enable unique learning experiences through different social configurations?

In the following section, we describe the design of Rainbow Agents (RA) – our museum exhibit and the related data collecting process. This is followed by the introduction of SCAMP, the analytical framework proposed in this paper, and how it is derived primarily from Sandoval's Conjecture Mapping framework (2014). We follow that with two cases of collaborative play with Rainbow Agents, both involving a variety of social configurations enabled through the designed affordances of our exhibit. We end with a discussion about the value of SCAMP for supporting analyses specific to interactive museum exhibits, and indicating opportunities for design revisions in productive manners for different kinds of social play goals.

a. b.

**Figure 1. Pictures of the Rainbow Agents exhibit installation at the West Coast science museum (left) and the East Coast science museum (right)**

### 3.0 Methods

### 3.1 Rainbow Agents – exhibit design

The Rainbow Agents (RA) museum exhibit is a video game exhibit at two major science museums – one on the west coast, and one on the east coast. The exhibit consists of three screens (Figure 1). Two of these screens are touch screens that are placed on a table; two visitors at a time play the game with these touchscreens. The third, much larger, screen is the “shared community garden” that acts as the gameboard. This screen sits up against a wall behind the two other screens. In the museum on the west coast, there is a mounted poster on the wall next to the gameboard screen that offers information about the game, including basic gameplay, educational goals, and logos of the funding agency and project partners (Figure 1, left). The exhibit is placed against a wall along a corridor and visitors can approach or pass the exhibit from either direction. In the museum on the east coast, the exhibit is placed in a room near the start of the second floor, with a poster outside inviting visitors to play a game. The museum on the east coast is located in one of the most linguistically (and highly ethnically) diverse neighborhoods in the United States. The museum reports the demographics of the audience as 34% White, 22% Hispanic/Latinx, 20% Asian, 11% African American, 1% more than 1 race, and 3% other. Almost half the visitors are students as part of a school group, who are not charged for entry to the museum. Numerous other community programs, and free Sunday morning access are additional avenues designed to support increased cost-less entry to the museum. Spread across a large campus, and a 3 floor building, this museum is widely renowned for well researched interactive science museum exhibits and programming. In this museum, the exhibit is placed in a room near the start of the second floor, with a poster outside inviting visitors to play a game.

The science museum on the west coast is partnered with a well-known university in a mid-sized city. Serving approximately 140,000 visits each year (pre-2020), the museum has granted over 23,000 free admissions, offered approximately 1,500 onsite and offsite workshops to schools. Survey data indicates that 39% of the visitors identify as white, and attracts visitors ages 4-7 (41% of children) and ages 8-12 (32% of children). The Hall has a similar percentage of visitors with disabilities (10% compared with 8% nationally), a higher percentage of those have learning (31% vs 19%) or auditory (20% vs 11%) disabilities. In this museum, the exhibit is placed on the side of the lobby directly facing the entrance. This contributes to an increased visibility of the setup, different awareness about activity taking place. Our research here, as well as the design of the museum exhibit, is centrally interested in the play and learning of middle school students, though we also pay attention to younger and older visitors, especially those playing alongside middle school learners.

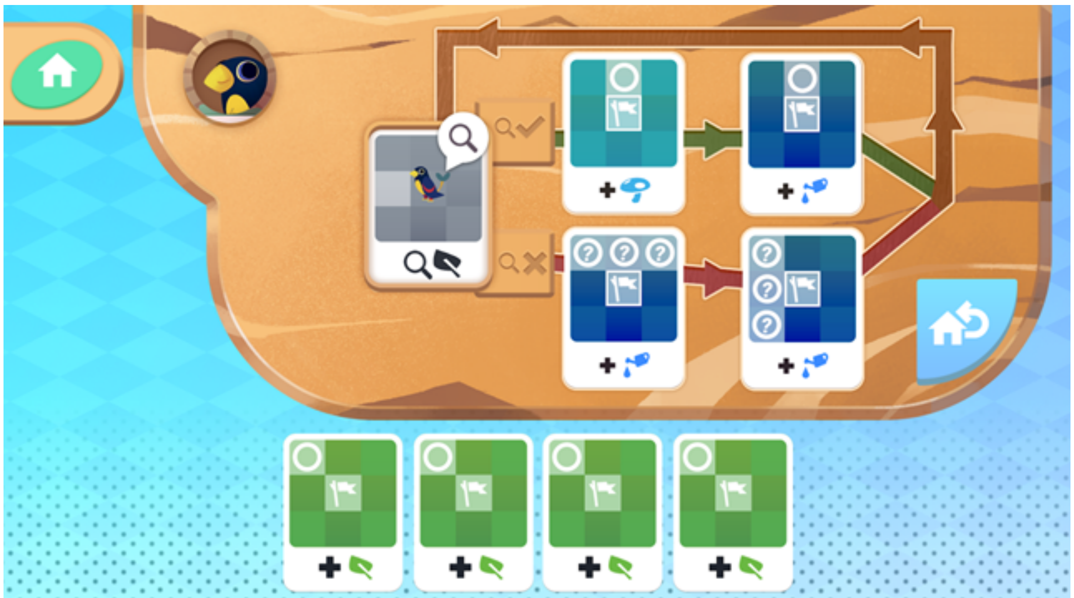


**Figure 2. The state diagrams which represent the sequence of instructions the garden agents follow (when programmed by the player). This image depicts the third agent, the bird's state diagram, which includes conditional and random logic.**

Typically, when visitors approach the game they sit or stand in front of one screen, or, station. From there, they can select an "agent" to place on the community garden. These visitors, interchangeably called players, then provide instructions to (/*program*) their (in-game) agent using a computational "state diagram" (Gooch, 2008) to complete tasks (e.g., water plants or place a new plant) in the garden (Figure 2). There are three different types of plants in the game: woody plants, leafy plants, and fungi. Players are rewarded with a garden-wide thunderstorm when the garden has sufficient biodiversity across these plant types.

The game includes three "agents" that can complete tasks in the garden. Players typically start with one agent – the hedgehog – and, as they advance, are presented with the second and third agent. The hedgehog follows simple deterministic instructions ("place a wood plant in this location," "water in this location," etc.). The second agent, a salamander, introduces randomness: it has instructions that allow it to randomly select the location within a specified area to conduct its assigned task of watering or planting. The third agent, a bird, adds conditional logic: it first executes an assigned task, then searches nearby for a specified plant type. If it finds that plant type it executes one player-specified task, if it doesn' t find that plant type, it executes a different player-assigned task. All of these player actions can be completed with a single touchscreen and require no interaction or coordination with the other player.

Players are free to water any square and plant any unoccupied square in the garden. To encourage players to seed different kinds of plants, "treasure chests" appear at random locations and intervals with a fixed frequency (a new treasure chest every 10-15 seconds). These chests can only be unlocked by seeding specific kinds of plants nearby – increasingly difficult treasure chests need more plants in their vicinity to unlock. Unlocking treasure chests rewards players with a rainbow plant. Rainbow plants are only placable by both players working in coordination. To place one, both players must select the button in the top left corner of the screen which will bring them to a new screen that includes a grid of the gameboard garden. On this screen, the player on the left can control the vertical position of the chest placement, and the player on the right can control the horizontal position of the chest placement. Once both players are satisfied with the chest position, they select a button to place the chest in the garden. This action is the only part of game play that *explicitly requires both players* to engage in the same activity at the same time. Choosing to place a rainbow chest is an optional act, however, and players frequently skip that choice.

The game includes no point system, levels, or fail states (although unwatered plants fade to gray before vanishing from the garden). Instead, the game invites players to create their own benchmarks for success and encourages a mixture of goals: aesthetic (garden beauty), achievement (how to open more treasure boxes or attain the rainfall), and learning (how to best use the more complex agents).

**3.2 Data collection (includes selection and participation of children)**

This game is designed for middle schoolers. We do not select for any prior experience or knowledge of programming or awareness of the exhibit, and are particularly interested in visitors who make sense of the programming aspects of Rainbow Agents before knowing much in advance.

The first case discussed here was conducted at the museum on the East Coast. The poster outside the exhibit room informed visitors of ongoing recording. Researchers stood in the same room as the exhibit taking field notes, and conducting semi-structured interviews with visitors who agreed to be interviewed. This case was selected using field notes and observing the multi-day recording data set to identify instances of social play which engaged a variety of social configurations.

For the second case presented in this paper, two museum docents conducted interviews with the players as they were playing in the museum on the west coast. The gameplay in this case initially centered around a middle schooler but also included their work with an accompanying adult, as well as much younger visitors who soon started playing beside the initial middle schooler. The interviews informed the visitors of the video recording and the exhibit's research goals. This case is a result of selective observation from the docents looking for engagement from our intended audience and sampling from the notes. This focal case included 18 minutes of video data (close to the beginning, till the very end of the middle schooler's gameplay), which is complemented by log data from the game, and observational notes from the docents. The log data collected includes all actions by the user, and states of the game, enabling us to analyze different levels of detail regarding in-game attempts, successes, and failures on the visitors' part.

This selective sampling to find cases of interest, is in line with the goal of this study - to illuminate the variety of social configurations made possible through specific design choices, and how to describe and analyze the strengths and shortcomings of different design decisions on the occurrence of these collaborations. These visitors were not recruited in any specific way and were part of the regular visitorship of the museum.

### 3.3 Analytical framework: SCAMP

As described in our research question, our goal is to understand the relationship between design features and visitor participation.

Informed by the information outlined in our literature review and these observations of visitors at RA, we present a conjecture map (Sandoval, 2013) and a coding scheme to describe visitor engagement. Figure 3 presents the conjecture map for our project's design goals. While Sandoval's Conjecture Map tends to categorize Discursive Practices and Participant Structures as Embodiments and Mediating Processes, studying different forms of collaboration as emergent phenomena necessitates that we consider them as outcomes of the design. Under *Participant*

*Structures*, we group different kinds of interpersonal roles (like Teacher, Observer, Partner, etc.), and *Discursive Practices* as play actions and durations.

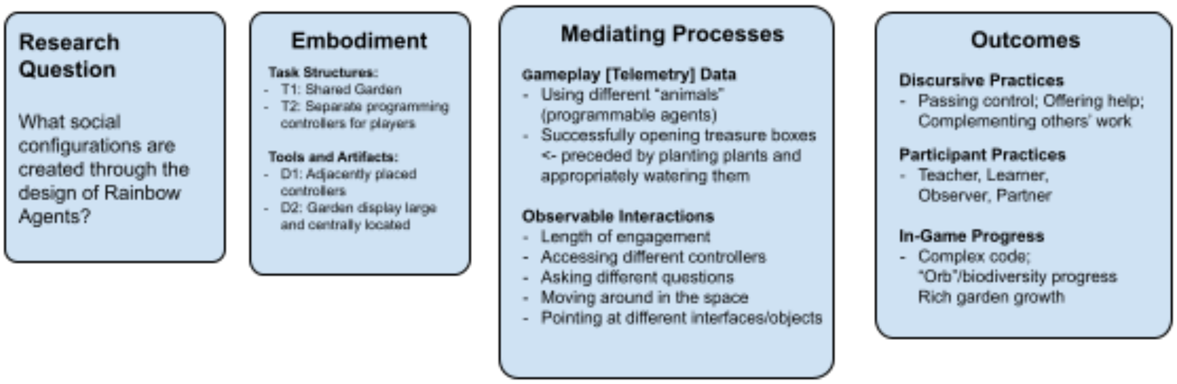



**Figure 3. Conjecture map to inform the components of the SCAMP analysis –particularly through the embodiment of Rainbow Agent's design, and its affordances for creating different social configurations among visitors.**

Conjecture maps are a commonly used tool in educational research to examine the relationship between the design of a learning environment and different learning outcomes of interest to the study. Conjecture maps provide a generalized model of examining these relationships, with no specific constraints on the sets of connections and outcomes that can exist. To examine the emergence of different kinds of collaborations around interactive museum exhibits, we created a specific conjecture map. Creating a coding scheme from this conjecture map helps us list and describe the different design-behavior relationships that emerge, and also has the ability to be used by other museum designers and researchers in the creation of specific research questions as well design ideas. We call this coding scheme SCAMP (Social Configuration Affordances for Museum Play). SCAMP involves recognizing social configurations of play around a museum exhibit using a coding scheme, and identifying relationships between the design features that support, hinder, or mandate certain social configurations (exemplified in Rainbow Agents and our cases).

**Table 1. The SCAMP coding scheme – shorthand for codes to describe play events, and their relationship to design features**

| **Design hypothesis** | | **Goal Orientation** | | **Play Action** | | **Duration** | |
|---|---|---|---|---|---|---|---|
| **Expectation** | **Code** | **Action** | **Code** | **Action** | **Code** | **Action** | **Code** |
| Supports/Enables | E | Parallel | Par | Playing | P | Short | S |
| Mandate | M | Collaborative | Col | Teaching | T | Long | L |
| Hinder | H | Competitive | Com | Receiving | R | | |

We categorize *play events* as sections of an episode which appear to engender particular social configurations, i.e. a combination of a specific *goal orientation*, a *play action* (which describes a certain interpersonal role) for a certain *duration* (relative to other play events in the episode). This categorization/coding scheme is depicted in Table 1. Goal orientations here are not descriptions of the task design themselves, but how players are pursuing goals relative to each other. Often players will simply engage in their own goals (especially in the beginning) without paying much attention to what other players are doing. In this case, they might be pursuing different or common goals compared to their co-player, but we label playing in such a manner disconnected from their co-players, as *parallel* play. This might not appear to be *social* play, but we find that labeling it as an event is valuable in recognizing initial and intermediate stages of a process that flow through different social configurations. When players are working together – towards a shared goal while helping each other – we call this *collaborative* play (ascribing to collaboration as per Roschelle, 1992, and many others). When players are working on conflicting goals, we call this *competitive* play. As seen in one of our episodes, competitive play is unique that it can emerge without having designed the game to support competition explicitly. If there is access to similar sets of actions, players can engage competitively in doing the same action "better" than the other (however they decide to operationalize this comparison). Thus, it is critical to be open to recognizing competitive orientations, and which kinds of design features create space for the emergence of competition. In addition to this, it is also important to not consider competition as always undesirable, as it is a familiar form of engagement that can lead to productive learning experiences if the design of a learning environment guides them into effective learning opportunities.

The choices of *play actions* in this study comes from condensing Tissenbaum, et al.'s (2017) DCLM framework – which include a variety of different social actions museum visitors engage in during informal play (Table 2). For this study, we want *play actions* to not be individual interactions that are typically momentary in nature, and instead convey a certain relationship between the interacting players. With this goal in mind, we describe the different play actions as *teaching* (combining narration, making suggestions, offering help), *receiving* (asking for help, receiving suggestions, observing others' work), and *playing* (interacting with the game).

**Table 2. The divergent collaborative learning mechanisms framework**

1. Mechanisms of collaborative discussion
    a. Making and accepting suggestions
    b. Clarification
    c. Negotiating
    d. Seeking help
2. Mechanisms for enacting divergent collaboration
    a. Joint attention and awareness
    b. Goal adaptation
    c. Boundary spanning actions
    d. Boundary spanning perception
    e. Narrations
    f. Modeling

Lastly, we describe the duration of these events as *short* or *long*. The duration of a play event is categorized depending on the length of engagement in a specific Goal Orientation + Play Action combination. This study differentiates between short and long events in relation to the different events within each episode, but these perceptions are also informed by broader work on the nature and context of the learning environment being studied. For instance, dwell times are often used as a first broad measure of engagement in museums (Falk & Dierking, 2018). The length of time visitors spend at different exhibits is used as a measurement of what is considered more interesting or engaging. While this is complicated by the interactive nature of our exhibits, understanding common forms and spans of engagement in interactive science museums can be used to provide anchors for what makes a short or long play event. Recognizing which configurations last longer than others, combined with how configurations change over time, helps develop an understanding of the experiences of visitors at the museum exhibit.

The first column describes a specific set of relationships that are relevant for analyzing interactive learning tools, in particular such digital playful museum exhibits. In games and similar rich interactive experiences, different features or (game) mechanics encourage certain kinds of engagement, sometimes force specific actions, and often discourage other kinds of engagement. For instance, cooperative board games like Pandemic encourage players to engage in collective decision making, and discourage engaging competitively, or in parallel play. If players don't actively share resources and ideas with others, and choose to pursue their own strategy, they and their teammates are much more likely to lose. Some other cooperative board and card games like Mysterium, Bridge, and others *mandate* a certain amount of disjoint problem solving. The rules prohibit players for revealing information that they have unique access to, and players need to attain a shared goal with limited communication and a certain amount of parallel play. On the contrary, competitive games like Chess, have mechanics that hinder collaborative play while *mandating* competitive play. At the same time, the context of gameplay like a tournament, a tutoring session, or just friends playing, can engender many different social configurations despite being engaged in just competitive play (for instance, learning as a spectator, engaging in commentary and speculation, and teaching a student or peer while actively playing against them). Examining these connections between design features and different social configurations are the goal of this study.

To understand the connections between the design features and the occurrence of different social configurations, these codes need to be coupled with a description of the design feature that played a role in their creation. In SCAMP, we describe the link between design features and social configuration using a compact representation of our hypothesized relationships and observed events. In this work, we use the colors from the table to refer to the different columns: Plain for mechanic/design embodiment, Pink for design hypothesis's relationship, Green for Goal Orientation, Blue for Play Action (embodying different interpersonal roles), and Yellow for duration. We use a few additional symbols in this representation to convey additional information and ambiguous hypotheses. When a mechanic enables multiple behaviors, we describe it by listing the relevant collaborative interaction features together (for instance Col/Com indicates both Collaborative and Competitive behaviors, and * indicates all three Play Action types).

We describe the most notable relationships in Rainbow Agents here, going through the design features enlisted in our initial conjecture map (Figure 3 - Design Embodiment):

- T1 (Shared Garden as a *Task Structure*): E | Col/Par | * | * (Enables Collaborative or Parallel Play across different Play Actions and Durations.) We designed the shared nature of the garden to foster collaborative play across different play actions and durations. Workspaces where one's work affects and is affected by others' work leads to an awareness of and interest in what others are doing. In some environments, this interference can lead to reduction of coordinated action and participation when learners/participants feel like they don't have space or autonomy to do what they want to (Meisner, et al., 2007). This can push players into parallel play, or even leave the shared venture! But if player-learners are able to engage with autonomy, working on shared ground while doing similar but mutually additive work can lead to collaborative goal orientations. Since plants around treasure boxes reward both players, and plants across the garden reward the whole garden with a thunderstorm, the lack of individualized rewards encourages players to coordinate their work with each other.
- D1: (Centrally Displayed Garden as a physical aspect of the *tools' design*): E | * | T/R | * (Enables Teaching/Receiving roles across different goal orientations and durations).

We have seen how being able to access others' work in process (Lyons, et al., 2015) or even just creative products without seeing the process (Halverson, et al., 2018) helps the learning and work across others in shared learning spaces. The central, large nature of the garden is of unique consideration as it is not just shared by the two players, but openly visible to all museum visitors around. This plays a unique role in inviting new players, and providing opportunities for passive observation and learning, as well as collective sensemaking and teaching-learning interactions. Being able to see others' pursuits also creates space to see what goals others choose which often leads to adopting common or similar goals. This varies from taking the form of building on the work done by other players, and/or attempts to "best" them. In Rainbow Agents, this can take the form of trying to work towards a more vibrant shared garden as a joint effort, or opening more treasure boxes than the other player as a competitive orientation.

- T2 (Separate Programming Controllers): E | Par | P | L (Enables Parallel Play for Long sessions) Here the separateness of the programming controllers is key to enabling parallel play for extended sessions. This is in line with Inkpen et al. (2009) finding that multiple input points lead to lesser collaborative play and more individual, disconnected play.
- D2 (Proximal Controllers): E | Col/Com | T/R | * (Enables Collaborative and Competitive engagement, particularly in the form of teaching and receiving actions of different durations) This hypothesis is in line with Marshall et al., (2009) and Antle et al. (2013) who found that overlapping and intersecting controls (in terms of proximity, number, and function) lead to players engaging with each other in a variety of ways.

Foregrounding these specific design features, demonstrates our focus on the object- and space-based nature of our analysis. A different SCAMP analysis could also focus on the specific interfaces and game mechanics and help understand how to design the game itself to support different social configurations. In the following sections, we present the two cases going through each different interaction pattern among the visitor-players followed by a discussion of the design to behavior relationship observed in that interaction.

## 4.0 Results

### 4.1 Case 1

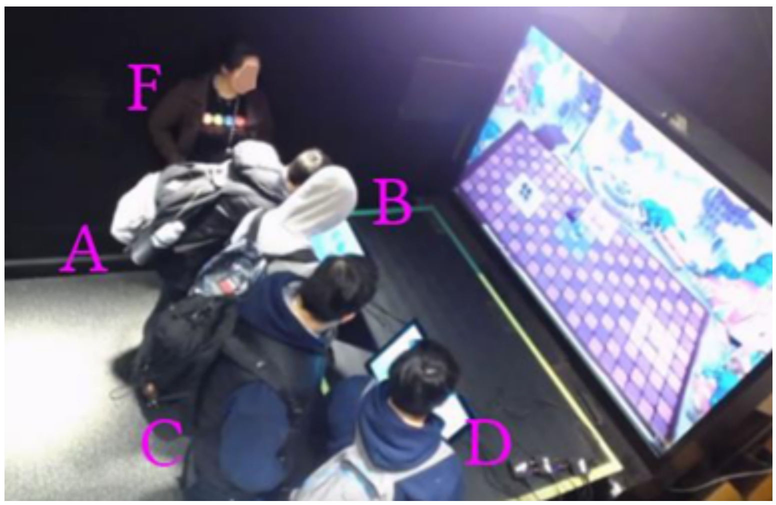



**Figure 4. Stills from the first focal case's video recording depicting the main characters of the case at the East Coast science museum**

Here we present a case of 5 boys who come into the room of the exhibit simultaneously, and transition through different forms of collaboration in their gameplay.

- D1/D2: E | Com | P | S (Centrally displayed garden and Proximally placed controllers Enable Competitive Play for a Short duration): The group approached the game and the players separated into two dyad groups (Player A & B; Player C & D – Figure 4). As the two dyads started to make sense of the game, they also tended to phrase the initial sensemaking process as a ‘race’, with each pair attempting to achieve the negatively interdependent goal-alignment of being the ‘first’ to figure the game out. Throughout this first phase of gameplay the two groups tend to move back and forth between sensemaking statements (stating potential hypotheses about the game’s mechanics) while also engaging in similar competitive banter back and forth, for example after the above exchange there is an argument about which group ‘got it right’ first, with Player D saying, “We also got it right over here… More quickly than you.”

In line with our expectations, the visitors perceived the arrangement of two controllers in front of a common screen as a stage set for competitive play. It seems plausible and likely that this (goal) orientation preference came from the familiarity of this setting to how video game experiences at home often look – with controllers in front of a television. This reinforces the need to be conscious of how the physical aspect of learning spaces’ design has strong potential to set the stage for how learners would begin engagement. At the same time, this interpretation is not shared by all visitors. Some museum-savvy visitors prefer to look for written instructions or other guidance to orient their goals, and others with different game and technology experiences perceive this setting differently.

This tension across different interpretations is uniquely valuable in spaces like museums. Science museums were driven by the vision of providing rich complex learning experiences across a wider variety of audiences than is often manageable within the confines of school curricula (Oppenheimer, 1968). Despite this, there is adequate evidence that marginalization from museum cultures, access to science identities, and physical access to museums are some of the many reasons science museums and their exhibits are still often inequitable in who they engage and benefit (Feinstein & Meshoulam, 2014). This invites the need to disturb what museums and their exhibits look like, and what engagements they welcome in contrast to extant practices. These visitors' familiarity with the environment in a way that enables them to engage is a success, but it also needs to be examined closely around which visitors feel unwelcome in the presented space. While we have observed visitors engage with the game in overtly non competitive ways – where visitors spend extended periods of time working on watering plants with the goal for ensuring plant survival (Kumar, et al., 2020) – we need to be wary of the proclivity to read this arrangement of tools as a (competitive) gaming space, since video games (competitive ones in particular) are often perceived as fostering sexist and racist cultures (Leonard, 2006), potentially reified in this first episode described above.

- T2 | E | Par | P | S (Separate Programming controllers enabling extended parallel play coupled with) +

  D2 | E | Col | T/R | S (Nearby situated controllers enabling extended parallel play): After a brief clarifying conversation with the facilitator, the players begin to move towards increasingly coordinated play: with individual players directing the action of others. For example, Player A has a realization about the color coding of cards, saying, "So if we place [these cards] over here, we get mushrooms…" B asks a clarifying question to that statement, "Wait, how do you know you got to place them over there?" A clarifies his reasoning, "Because [the color of the cards and chest] match. Perfectly." B clarifies again, "Because they're purple?" and A agrees, further giving B an imperative command to execute on the screen, "Yeah. They match. Okay… so you just put purple in, and it'll work. Like… this one will go here [pointing]." C and D are developing their own understandings of the game. This represents both the parallel play enabled by separate controllers, as well as teaching/receiving opportunities by the proximity of their work to each other. Another implicit design feature that enables this conversation to be productive is the fact that their tools (each controller) have similar abilities and mechanics of usage. As a result, they are able to individually *and* collectively make sense of a similar set of symbols, mechanisms and concepts.

- D1 | E | Par | T/R | S (Centrally placed large display Enabling Parallel Teaching/Receiving Short interactions) This co-development of understandings is exemplified as C and D continue to work in a different part of the shared garden. D is talking excitedly about his strategy, while C is not a very active player, but appears to be listening and responding. D points to the main screen, saying, "Ooooh, we need to get the [avatar] to go over there [pointing]." C shrugs, and unenthusiastically says, "Ok…". This also sets the stage for the beginning of collaborative play through the same designed affordance.

Here D2 | E | Col | P | S is represented for a short time as well: As the players begin to grasp the game and experience small successes, they start to work collaboratively as well – breaking out of the dyad structure, and moving into a formation where all four players are actively working across both screens to communicate and formulate strategies.

As collaborative play becomes the predominant mode, the task structures become overt drivers of collaborative strategizing. T1 (Common Garden as a shared area of work) | E | Col/Par | P | L An example comes as Player D first realizes the plant wilting mechanic, saying, "[pointing at the main screen] Look, yo, the plants are dying out!" Player B looks up, and with alarm says, "Wait, the plants are dying!? … Wait, what does that mean?" Player D points again, saying, "Look, they're turning gray. … Go back to the other animals [meaning the simplest state agent] since they're dying out. Look, everything is turning gray." Both dyads work towards maintaining the garden, and after a few minutes their efforts pay off as they figure out the mechanism to unlock chests, triggering the collaborative slider mechanic, with all players providing input to the group description such as “You guys want to place it on a chest? One higher…” and, “No, one lower.” Player A addresses the main group, saying, “I'll go there and help them out,” and B connects with that, saying “So, it’s a team effort, right?”

**4.2 Case 2**


**Figure 5. Stills from the second focal case’s video recording, at the beginning and the middle, depicting the main characters of the case, at the West Coast science museum**

Here we present our second focal case, which began with a middle schooler in a gray t-shirt (herein called Gwen), beside an adult in a black jacket (herein named Beth). Over the space of 18 minutes, Gwen almost always stays at her station, having placed and programmed the three agents 139 times. In contrast, Beth does very little work while sitting at her station for approximately 9 minutes, and then relinquishes control to two much younger visitors in a grey shirt and a white dress respectively – herein named Luke and Whitney. They play for the remaining 9 minutes. Luke, Whitney, and Beth collectively place the three agents 59 times on the other station (herein called Station 2). This playthrough also sees two thunderstorms, at 10 minutes 30 seconds into the video and at 15 minutes 50 seconds. We use this as indicative that Gwen likely tried to cultivate enough plants to trigger the thunderstorm throughout her gameplay. The second thunderstorm is visibly triggered through the collaborative work of all three players at the two stations.

We now describe the 7 different social configurations supported by RA exhibit's design that take place in this particular sequence which consist of visitors negotiating participation and building understanding surrounding the game. We also pair those descriptions with a discussion around how the design features enabled the social configurations and the learning experience they provided.

1. D2 | E | * | T | S (Proximal player controllers Enabled Teaching interactions for a Short time regardless of Goal Orientation): Beth (likely parent) is an onlooker, hesitant to participate, while Gwen (child) is constantly working at her screen. Four times she reaches across and controls Beth's screen: twice to control a collaborative game mechanic, twice to explain to Beth how to participate. 5 minutes in, Beth does make a few attempts to place an animal and program the corresponding state machine. This teaching of games from children to parents is a valuable and unique dynamic as it empowers children/young learners as holders of valuable knowledge that adults need or can use (Zimmerman et al., 2010). This is productively sustained for Gwen's growth in this particular interaction, as Beth is receptive and respectful of Gwen's explanations. This interaction can be described under the SCAMP framework with the description
2. D1 + D2: E | Par | R | L (Central Screen and Nearby controllers Enabled Parallel Receiving for a Long time span), coupled with T2 | E | Par | P | S (Separate Controllers Enabled Parallel Short Play): 6 minutes in, Whitney and Luke start hovering around Beth and Gwen. While being onlookers of the shared garden and the current players' (Beth and Gwen's) programming

interfaces, Whitney tries to join in and participate through Beth's screen, especially since Beth is not actively engaging and only looking at Gwen's work (on Gwen's programming screen and the main garden). This is an opportunity for learning that is afforded by the visibility of tinkering performances in this space (Lyons et al., 2015). There is also an aspect of how the onlookers, initially peripheral participants to the exhibit's gameplay, become central participants through their self-insertion into the activity (Lave et al., 1991).

3. T2 | F | Par | P | * (Separate but Limited Controllers Forced Parallel Play across different durations): 9 minutes in, Beth leaves screen 2 thereby relinquishing control to the hovering kids. This is reminiscent of the criticism of how limited controls can lead to competition over play (Marshall et al., 2009). The passage of controls in this case was smooth, but it did involve the kids waiting for a significant amount of time. As mentioned in event 2 (the last point), there was a shortcoming in the social norms of a museum as well as no designed affordance to support helping newer visitors participate. This presents possible design opportunities to encourage action on idle screens; and also to structure opportunities to pass control.

4. D2| E |Col | P | * (Nearby player controllers Enabled Collaborative Actions): Whitney and Luke share a seat and are seen smoothly negotiating control over screen 2. Whitney spends more time touching the screen, but both move between touching the screen, looking at Gwen's work on her screen, and the happenings on the central screen together as well as separately. These interfaces are designed as avenues for choosing and setting goals, as well as seeing other players' products and processes. Gwen continues to focus on her own screen throughout. Whitney and Luke engaged in a notably fluid transition between learning from their neighbors and taking control of the interface from each other. This kind of collaborative work and learning is uncommon among learners from dominant demographics in the US. Mejia-Arauz et

al., (2018) observe young learners from families of Mexican heritage engaged as an *ensemble* – engaging in smooth nonverbal transfers of control between each other – during a problem solving activity, much more than learners of European heritage. This points to the need of expanding conceptions of collaborative activity, as well as the underlying values that are promoted as positive practices of collaboration. The design of learning environments should also enable support such a plurality of participation while being aware of the strengths as well as shortcomings of dominant collaborative practices like turn-based transfer and verbal communication of different processes and actions.

5.D2 (Proximal player controllers)| E | Col | P | * : Later during play, Gwen offers help to Whitney and Luke. This reflects Gwen expressing expertise, which has been gathered from her sustained work over the last 10 minutes. This offering of guidance, and pushes towards collaborative play is often designed for through task structures and discursive practices in other environments. Even in Rainbow Agents, there are task structures (like the reward and placement of rainbow plants) that are intended to nudge players towards active collaborative work. Antle, et al., 2013 demonstrate the learning value of fostering such experiences, in their work with YouTopia which forces players to work together at certain junctures, so they have to discuss their understandings and goals with each other before proceeding.

6.T2 | M | Par | P | * (Separate programming controllers Mandated Parallel Play): At the above offering of help from Gwen, Whitney says "Let's just do our own thing... and if we win, we can give each other a high-5!" In contrast with YouTopia's forced collaboration design (Antle et al., 2013), our design's deliberate affordance for parallel play leaves space for learning from each other, and also allows for independent goals and sensemaking, rendering an experience unique to learning a breadth of different ideas, together and separately, from multi-user museum exhibits. As we can see from these results, the players developed their own patterns of placing cards throughout the gameplay, and tend to test out their own hypotheses based on their previous card arrangements as the pattern of using cards tends to become more complicated from the initial one card placement to the 2-card or 3-card combinations later on.

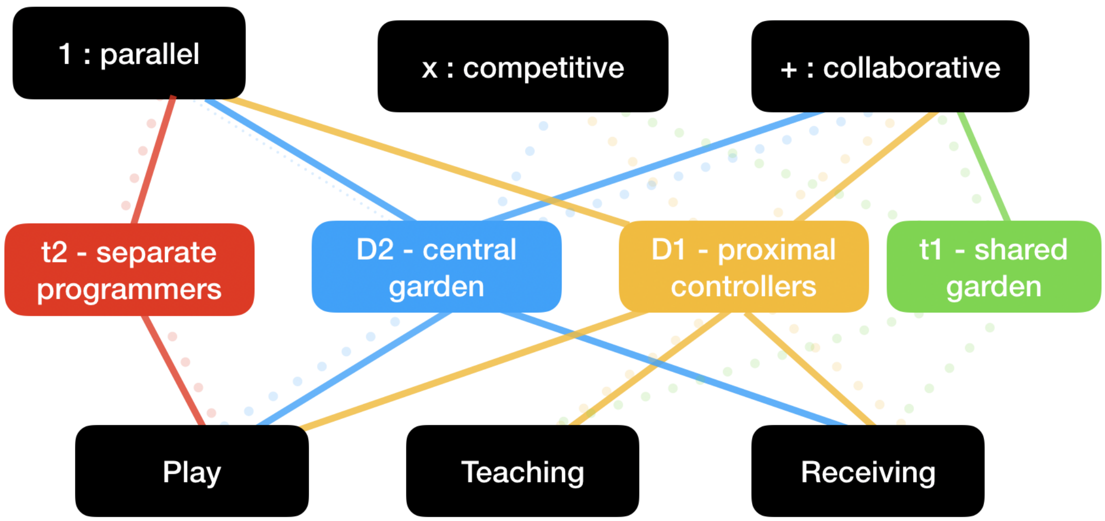
7. T1 + D1 | E | Col | P | S (Central & Shared garden Enabled Collaborative Play for a Short duration): Around 15 minutes in, while Luke is intently following Whitney's actions as well as Gwen's products on the shared screen, he points as he sees the different plant type orbs fill up. He calls attention to the upcoming storm, which everybody looks up to see, exemplifying joint attention enabled by the central shared screen which exhibits the products of each players' work. This event triggers conversation between the participants and they increasingly look at each others' screens. It provides an inroad into collaboration supported by the proximal controllers (D2: E | Col | * | * ). Unfortunately, this case is cut short by Beth returning to move Gwen away from the exhibit, who is promptly replaced by another new player. Our video clip ends at this point, since all remaining players at the exhibit were noticeably younger than our intended age group.

**5.0 Discussion & Future Work**

The SCAMP framework allows us to examine how the design features interact with the observed play. Although one would expect two single screens to afford just individual, isolated play, our SCAMP description maintains consciousness of the value of the other controller's proximity and how this enabled collaborative play and teaching events across screens. Allowing players to become individual experts on their own screen allowed them to pass knowledge gained during solo play into a social context. It is notable how, repeatedly, in the second focal case (particularly events 1 and 5), parallel play prompted teaching and receiving events and collaborative actions. The development of independent expertise across different players was particularly well suited to teaching each other about the progression of events of the solo play. This supports prior work on the value of parallel learning enabling richer collaboration.

It is evident that none of the described features necessitate collaborative play, beyond a few interactions. Despite that, what we see is that the minimal prompting of collaborative events – like the thunderstorms that are triggered by everyone's work and affect all plants in the garden – tend to prompt further unforced collaborative play and teaching among players. Once the "play ice" has been broken, the players are much more open to playing collaboratively. This takes place in both our cases: collaborative play and joint attention (Tissenbaum et al., 2017) emerges despite explicit claims for parallel or competitive play earlier.

Our initial hypotheses were reasonably simple and well supported by the literature, but they fell well short of the observed behavior through unexpected interactions between the design features.




The dotted faded lines depict the expected affordances of the design features, and the solid lines are the ones observed in this case. Most notably, D1 and D2 (the Central Garden and Proximal Controllers) afforded Parallel | Receiving – the benefit of learning as an onlooker when other players' tinkering is available for public viewing (Lyons et al., 2015).

In addition, the end of case 2's event 7 marks an interesting form of Collaborative/Parallel Play, afforded by D2 (Proximal Controllers), where without any articulated Teaching/Receiving, or even goal coordination (Roschelle, 1992), the players being aware of each others' work enabled them to pursue overall "win conditions". This is particularly enabled by mechanisms within T1 (the shared garden) where both treasure boxes, and orbs corresponding to biodiversity, are affected by both players positively and also reward both players' work and gameplay simultaneously.

The timeline of events in case 2 is:

D2: E | * | T | S

D2 + D1: E | Par | R | L

T2: F | Par | P | *

D2: E | Col | P | *

T2: F | Par | P | *

T1 + D1: E | Col | P | S

D2: E | Col | * | *

The way in which instances of parallel/solo play flow into collaborative play (and other interactions) becoming more common, is a reflective case of how active social engagement becomes more common.

In this case, and other informal observations, we have found that the collaboration sticks around, in different *flavors*, and students continue to teach and cooperate while acting with varying amounts of independence. Our suggestion is then that the design elements afford ‘stickiness’ – that is, the degree to which social configurations persist. It is not surprising that people collaborate more once they have successfully collaborated, but the SCAMP-support analysis highlights design research possibilities of specific interest.

More research is needed to explore which design features prompt more or less sticky/persisting collaboration. When does the social configuration persist across the session? For whom are the social configurations sticky? Which configurations are more “naturally sticky” (i.e. if they happen with design prompting, they are likely to happen again) and which configurations only become sticky after multiple design events?)

In further work, we hope to tease out a more complete picture of SCAMP and when SCAMP prompts the stickiness of social configurations. At the same time, the popularity of dark design patterns in many game-like environments (Zagal et al., 2013) pushes us to be cautious of how we design for sticky modes of interaction. Future work extending SCAMP analyses need to integrate measurements of learning and progress and differentiate between more and less valuable social configurations in different environments.

## 6.0 Conclusions

To conclude, this work provides the description of and illustrative uses of SCAMP: an analytical framework for researchers and designers to examine social interactions in museum exhibits. Social learning is often underemphasized in museum evaluation research by both researchers and practitioners (Hornecker & Ciolfi, 2019). We have detailed novel ways to use design features (both in-task activities and physical layouts) to support or hinder users as they engage in different social modes. Our SCAMP system foregrounds how specific features can act as invitations to start engaging in new social modes, which – if facilitated – can lead to sustained new social pathways for learning in museums (and hopefully beyond).

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**Statement & Declarations**

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