NISE network
NANOSCALE INFORMAL SCIENCE EDUCATION

Gaming and the NISE Network:

A Gameful Approach to STEM Learning Experiences

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www.nisenet.org

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Introduction

The NISE Network

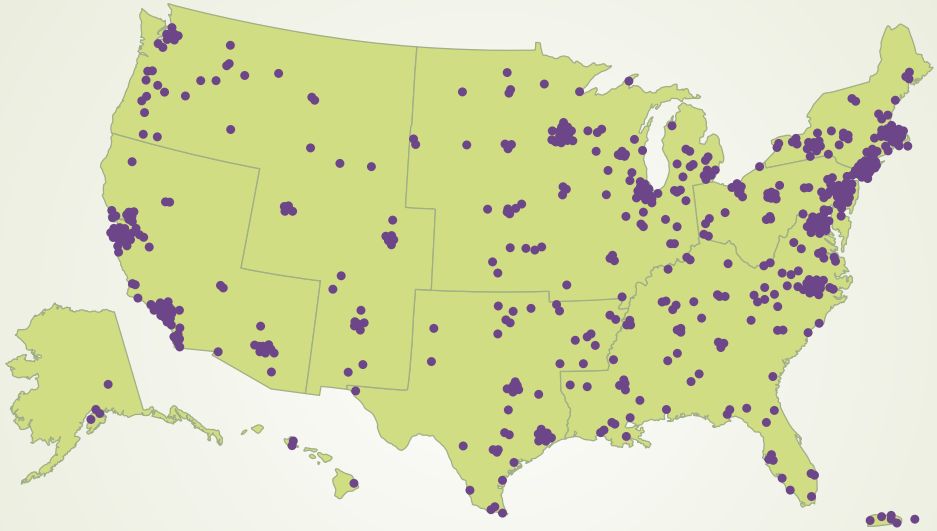
The Nanoscale Informal Science Education Network (NISE Net) created a national community of researchers and informal science educators dedicated to fostering public awareness, engagement, and understanding of nanoscale science, engineering, and technology ("nano"). The goals of NISE Net are to create a national community of partners to engage the public in nano, to develop and distribute educational experiences that raise public awareness and understanding of nano, and to generate knowledge about public and professional learning through evaluation and research.

NISE Net includes around 600 museums, universities, and other organizations that regularly participate in Network activities. The Network is organized into regions, each with a regional hub leader that serves as the primary point of contact and provides advice, encouragement, and support to partners. Network partners work together to engage the public in new topics related to science, engineering, and technology. Collectively, our efforts give the Network broad reach to diverse public audiences across the United States.

NISE Net created a network of over

600 ORGANIZATIONS

that regularly participate in Network activities



600+ partner institutions

- **45%** *museums and science centers*
- **34%** *colleges and universities*
- **20%** *libraries, K-12, government*

2,700+ professionals

- **71%** *educators, coordinators, and outreach staff*
- **18%** *researchers, scientists, and engineers*
- **12%** *both or other roles*

The Network develops our educational products collaboratively, taking advantage of the talents of educators and experts from museums and research institutions across the country. Our development process includes peer review by educators, prototyping and testing with the target audience, and review by scientists and other experts.

Engaging the Public

NISE Net's educational materials are designed to engage a wide range of audiences in learning about complex scientific content in ways that are fun and easy to understand. Our website, ***nisenet.org,*** offers hundreds of open-source educational resources that suit different educational contexts, engage diverse target audiences, and convey a range of content.

NISE Net products include programs for families, school groups, and other audiences that participate in learning experiences at museums, through university outreach, and in other informal settings. Our programs include educator-facilitated learning opportunities such as presentations, demonstrations, hands-on activities, and theater. Some incorporate media elements such as films, videos, graphics, and multimedia experiences. Others are designed to enrich or extend the learning opportunities offered through NISE Net exhibits.

Why Games

Games are everywhere in our world, from casual gaming apps for phones to classic board games for family game night. Many games rely on a core social experience that heightens the excitement. Think back to that first time you beat your brother, sister, or best friend in Monopoly® or when you made a new professional connection while playing a less than dignified icebreaker game! While entertaining, games also hold a special place in many of our memories as rewarding challenges that are overcome through practice and learning.

Educators have noted the tremendous potential for engagement and personal relevance in gaming. Fun and absorbing games motivate and support a wide range of learning by using clear incentives, providing timely feedback, granting a sense of control, and encouraging critical thinking and communication. In the United States alone, teachers are frequently bringing educational games into the classroom, while parents and caregivers often encourage the use of games and other educational media in the home (Takeuchi & Vaala 2014; Rideout 2014). Libraries, museums, and other organizations that support free-choice learning have also taken a closer look at incorporating playing and designing games in programming intended to engage broad public audiences (Nicholson 2010 and 2012).

Given the growing educational interest in games and the possibilities they offer for STEM learning, NISE Net program developers have experimented with a variety of gaming styles and structures. These have included hands-on activities, stage programs, exhibits, and media over the last decade. This guide summarizes these efforts by highlighting lessons learned through both the development and implementation of games in the Network.

About This Guide

The Network experimented with many game formats over our decade-long project focused on nanoscale science, engineering, and technology. This guide focuses on a handful of examples, ranging from simple card games to large-scale exhibit components,

to illustrate approaches we found successful for incorporating gameplay into informal STEM learning experiences. More information about the full collection of NISE Net educational materials can be found on the ***nisenet.org*** website.

Relationship Between Gameplay and Learning Objectives

NISE Net created several frameworks that articulate content, learning, and design goals for all products developed by the Network and distributed to our partners. Within the set of learning principles (Ellenbogen et al. 2012), NISE Net program developers saw exciting possibilities for using games to scaffold specific experiences for visitors. The learning principles are grouped into three kinds of actions by participants: *imagining the nano world; exploring scale and properties; and connecting nano and society.*

Many of the representative behaviors underlying the actions in the left column of the accompanying table strongly match outcomes frequently associated with gameplay in the right column. For example, a visitor is more likely to pay close attention to the relative scale of objects if it is a fundamental piece of information in a card game; likewise a visitor may easily slip into the role of a character affected by nanotechnology while acting out a future scenario in a group. These potential connections, along with the high levels of engagement normally associated with games, motivated the Network to include games within many types of educational products. Games frequently appeared in NanoDays kits, our most widely used product and the centerpiece of the annual outreach celebration of all things nano held by Network partners nationwide.

NISE NET LEARNING PRINCIPLES	GAMEPLAY OUTCOMES
1. Imagining the nano world • Explore the relative size of macroscale, microscale, and nanoscale objects • Use tools (or models of tools) that allow us to investigate the nanoscale world • Examine magnified images and models of the nanoscale world • Talk about how we can apply our knowledge of the nanoscale world to create new technologies	**Games and imagination** • Foster play • Stimulate the imagination • Encourage the use of tools and information to complete a task • Reinforce awareness of a model or vital information through rules of competition or collaboration
2. Exploring scale and properties • Observe phenomena demonstrating the relationship of scale, properties, and forces • Manipulate materials and explore the resulting changes • Reflect on the nanoscale world and how it works differently from the human scale world • Consider how knowledge about the nanoscale allows us to create new materials and technologies	**Games and exploration** • Place the player in charge while discovering a new topic • Support introspection • Motivate multiple attempts on a puzzle or challenge • Increase focus and attention while looking for clues
3. Connecting nano and society • Recognize that nanotechnologies may help us solve problems that traditional technologies cannot • Envision a future in which nanotechnologies are an important part of our everyday lives • Evaluate the responsible development of nanotechnologies by considering values, risks, and benefits • Discuss the role of individuals and groups in shaping the development of emerging technologies	**Games and connections** • Break down the barriers for social interaction by providing a safe pretend space • Precipitate the formation of teams • Allow people to take on different roles as players • Start conversations and encourage players to ask questions of each other • Inspire an emotional connection

Source: *Nanoscale Science Informal Learning Experiences: NISE Network Learning Framework* (Ellenbogen, Livingston, Ostman, Bell, Garcia-Luis, Johnson, Martin, Porcello & Zenner Petersen, 2012).

Over time, three primary game development and implementation strategies emerged in NISE Net's experience:

1. We favor game designs that **foster positive social interactions** between visitors.

2. We use **familiar games with simple rules** to quickly and easily engage visitors.

3. We design **experiences that are fun for all ages** by creating gaming challenges that are appropriate for young children, as well as older children and adults.

While these three categories are not mutually exclusive, they are a helpful way to organize the Network's history with gaming. In the following sections, each of these strategies is described in depth with examples that showcase beneficial gameplay, specific outcomes, and lessons learned.

Game Development and Implementation Strategies

1) Fostering Positive Social Interactions

Museums and other informal learning settings are social spaces where people come to spend time with others and learn together. In museums, we witness families talking about important issues, parents encouraging their children to explore through questions, siblings competing against each other, or friends quizzing one another on their beliefs. We found that games relying on these types of ordinary social interactions could provide comfortable pathways into complex nano content for visitors. Games offer our visitors a chance to tap into a common cultural framework to jumpstart their discovery of nano through shared experiences of competition, collaboration, and plain togetherness. In this section, we will review how several NISE Net products use gameplay with distinct social characteristics: (1) *Powers of Ten Game,* (2) *Nano Around the World,* and (3) *Big Fish, Little Fish* and *Ready, Set, Self-Assemble.*

1a. Powers of Ten Game

Powers of Ten is a simple card game exploring the relative sizes of various objects. Players compete to organize their hand of cards into lists of objects from largest to smallest.

BACKGROUND AND GAMEPLAY

Scale is a difficult concept for many learners, and the Network has tried numerous learning tools and visuals to help them explore and understand just how tiny things are at the nanoscale. The graphic design of *Powers of Ten* uses an easy-to-follow scale range with large numbers in addition to corresponding colors and icons. A poster is also provided to reinforce the scale of playing card objects for both visitors and facilitators. To play the game, players are dealt five cards, and must place cards above or below a row of three starter cards based on scale for each turn. Smaller objects go at the bottom of the row, larger objects go at the top, and no card can be sneaked in the middle of a row. Whoever gets rid of all their cards first—or has the least number of cards when no other cards can be played—wins.

OUTCOMES AND LESSONS LEARNED

A wide range of audiences enjoy *Powers of Ten,* and many partner museums use the game during their NanoDays events and other programming. As with many Network products, the simplicity of *Powers of Ten* allowed visitors and facilitators to jump right in and start exploring.

For participants to compete, they were required to use the presented tools and information about scale. *Powers of Ten* offers a reward when players are able to use their understanding of scale to strategically block another player. Players also receive immediate feedback about scale order when they're blocked or play cards incorrectly.

Although players compete against each other, at the same time they collaboratively build a scientifically accurate model of scale stretching from atoms to galaxies with only a few basic gameplay

"The Powers of Ten *card game was particularly popular at our institution and will be used by staff all over for a variety of activities. Volunteers LOVED it, and visitors asked where they can purchase the cards!"*

– Karine Thate, Museum of Science, Boston, Massachusetts

rules from the facilitator. The resulting model is often interesting enough that facilitators keep the last hand on the table after gameplay to attract a new set of players.

Due to gameplay, nano content associated with scale quickly became more relevant compared to when reading the same information on a static display. This scaffolding overcomes a shortcoming of earlier scale graphics tested by the Network. Formative evaluation showed that less than half of museum visitors looked closely at or thought deeply about the nanoscale when presented with a static scale ladder poster (Ma 2007).

LESSONS LEARNED FROM DEVELOPING AND IMPLEMENTING *POWERS OF TEN*:

Learning can emerge from competition. Focus and attention come more naturally while competing in a game. This can be a great opportunity to dovetail the necessary rules of the game with models or concepts from STEM topics.

Keep it simple. With or without STEM content, it will be hard to get visitors to invest time in a complicated game they may only play once. It's more fun for everyone if the rules are simple and players can jump right in.

Everyone gets a turn. Turn-based games like *Powers of Ten* give a chance for shy or young visitors to be in control for a length of time, even with an active group present. This can be empowering and add to the motivation for learning.

Adding extra materials for simple games creates more opportunities to play. Network partners using *Powers of Ten* during NanoDays reported they ran large games or many simultaneous rounds because of the extra cards included in the physical kit.

Present important information in a variety of ways, to work for different age levels. Adults familiar with scientific notion were able to use the +/- numbers on *Powers of Ten* cards to learn more about the size of objects. Knowing this fact was not required to play the game but helped some visitors order their cards.

Materials can be adjusted to increase accessibility for different audiences. A standard playing card size was chosen for *Powers of Ten* because it is easy for most people to manipulate smaller cards, but larger cards can be printed to increase accessibility for low-vision audiences.

VARIATIONS ON *POWERS OF TEN*

Many games can be tweaked to work better for certain audiences or settings. Because the main objective of *Powers of Ten* is so simple—lining things up in size order—many variations are possible. Here are two examples of different ways Network partners have adapted and used this game.

▪ Alternative version for groups and classroom settings

This game is easy to adapt to work for larger groups of learners, such as K–12 classes, afterschool programs, and summer camps. NISE Net created a version of this game using larger printed versions of the playing cards where participants each have a card and arrange themselves in size order. This gets the group up and moving, and can be used with the entire group or a handful of volunteers.

▪ Alternative version for professional development training settings

One fun variation of this game is well suited for large groups of teachers or meeting attendees. Players are given a card and told not to look at it. They stick the card on their forehead so other players can see their object but they can't. Without speaking to each other, the players must now physically arrange themselves in order of scale. Not only is this is a great way to get everyone up and moving around, this really helps participants practice their non-verbal communication skills and work as a group, all while learning about scale!

1b. Nano Around the World

Nano Around the World is a role-playing card game designed to get participants to reflect on the potential uses of nanotechnology across the globe.

BACKGROUND AND GAMEPLAY

Nano Around the World is designed to explore the complex relationship between nanotechnology and society through an engaging role-playing game. The game is ideally suited for a group of around 20 players. Each player receives three cards: a character card, a current technology card, and a future technology card. They are asked to assume the role of their character and given the objective to find nanotechnologies that might benefit them. After learning about their assigned character, they are set loose to engage with the other players/characters in the room. Beyond the quick setup of gameplay, there are no rules for trading cards. The players decide how to exchange, trade, give away, or even steal technologies.

At the end of the game, the players have a group discussion and determine how to name a winner. This debrief is often spirited and humorous, as participants describe the plight or triumphs of their character. The facilitator guides this discussion to help players reflect on the choices they made, the difficulty in finding appropriate technologies for many of the characters, and the possible nanotechnologies that could benefit a wider array of people than current nanotechnologies do.

OUTCOMES AND LESSONS LEARNED

Nano Around the World encourages participants to explore complex societal and ethical implications of nano using easy and intuitive social interactions. It works best for individuals with relatively strong reading skills, and has been used for museum visitors, as a staff/volunteer training tool, and in K–12 teacher professional development. (NISE Net also created a shorter, family-friendly version of this game called *You Decide,* which was included in NanoDays kits for use on museum floors and at family-friendly events.)

The game format provides a safe pretend space to discuss potentially controversial subjects and consider both altruistic (e.g., sharing and protecting) and selfish (e.g., stealing and exploitation) behavior. The freedom provided by the lack of rules in the game often results in unexpected emergent behavior, similar to the real world. And the game also creates a compelling reason for strangers to talk with each other, making it effective as an icebreaker. In the Network's *Nano & Society* professional development workshops, this game was one of the participants' favorite activities (Lundh et al. 2014).

In many products, the Network experimented with adding questions and reflection prompts about societal issues to fun, engaging hands-

on activities. But *Nano Around the World* flips that model on its head, and uses these complex issues as the hook through gameplay. *Nano Around the World* helps players recognize and reflect on the responsible development of nanotechnologies by considering values, risks, and benefits, in the context of their gameplay roles. The game also makes it possible to use humor and fun to help players recognize and talk about how single individuals can impact whole populations with emerging technologies.

LESSONS LEARNED FROM DEVELOPING AND IMPLEMENTING *NANO AROUND THE WORLD*:

Role playing works for all ages. Adults often have many built-up social inhibitions, especially speaking up in groups. Role playing in games is a helpful device to get people out of their comfort zones and ready to learn about and address complex STEM topics. And of course, many kids love to play different characters.

Experimenting with no rules in gameplay may surprise some visitors, but the freedom can also open new doors. Some players may feel unsure about being asked to play a game with a single objective and no rules for trading cards. It may not work for all games or all groups, but in this case the unstructured gameplay makes an important point: in the real world there are no universal "rules" for how new technologies are developed and adopted.

Design of playing materials is important. The cards in *Nano Around the World* went through multiple rounds of iterative design improvements with user feedback. Simple headlines and brief text, color and logo clues for categories, and large, compelling images are all good design choices when considering game development. Players need to be able to quickly grasp essential information.

Printable games can be easily reproduced and shared by anyone. All NanoDays products have a free, downloadable digital version that is designed to print on a standard office printer. Games like *Nano Around the World,* which require only printed cards, are accessible for educators on a budget.

When developing games that include sensitive subjects, work with experts and test with target audiences. Games are a great way to bring up topics that people feel apprehensive about in other situations. If you want to tackle tough topics in a game, consider asking an expert in that area for advice—they're likely to know common issues that come up and effective strategies for keeping the experience positive and productive. *Nano Around the World* would not have been possible without dedicated social scientists working side by side with museum educators during development.

CASE STUDY:

Nano Around the World

Frank Kusiak
Lawrence Hall of Science
University of California, Berkeley

I led a group of about 40 community college students in a large session of *Nano Around the World* as a way to finish off an afternoon of nanotechnology research talks. The students were very enthusiastic about the game. It allowed them to move around and interact with others after sitting and listening to several presentations.

The characters gave the students something easy to talk about. Every time students interacted with a new potential trading partner, they'd have to explain who they were, describe their technologies, and explore what each technology meant to their character. In order to make a trade, he or she would need to explain why a technology they possessed would benefit the other character while at the same time expressing how the other character's technology would work better in their own hand. The best conversations came from technologies that could benefit both characters: unless someone was very convincing, rarely did a technology trade hands in these cases, but the conversations (pulling at heart strings for the downtrodden character) were always interesting.

The students came to identify with the characters they were given. It seemed those who had characters from disadvantaged backgrounds were the most ardent advocates and really played on people's emotions to trade technologies. Those with privileged characters were more relaxed about trading because their character already did well enough before receiving potentially game-changing technologies. This group also felt like they had the most leverage, too. It was no surprise when they were able to wheel and deal technologies out of the hands of less privileged characters with material promises tied directly to their wealth and status, like a new job or money.

Of course, with no rules unexpected things are bound to happen. Some of the overly enthusiastic students would steal cards left on tables or even out of people's hands! The latter only happened once and I promptly gave the card back to the original owner after the group pressured them to return it. Despite the game having no restrictions on this type of behavior, the players soon worked together to decide what was and was not acceptable.

While most students would try for simple win-win trades, I saw other types of behaviors. Many times, they would try to find a trading partner who desired their unwanted technology. In return, he or she would get a technology that benefited their character or was potentially desirable to another trading partner. Others found more creative means to acquire technologies: a rich character "adopted" another player whose character was a poor child. She got all of the "baby's" technology. A wealthy character hired another player and promised to bring them to their country for steady work in return for one of their technologies. This person was left with one unnecessary technology, but they had a job! Another group formed a cooperative and shared their technologies freely among the four of them (even though their characters were geographically separate). The biggest loser in the game that I can remember told me, "I have no idea why I have one useless technology left...I guess I just forgot to get anything in return." In the end, our groups decided there was no clear winner, except for my coworker who sneakily stole all the undealt cards and started his own nanotechnology monopoly!

1c. Big Fish, Little Fish *and* Ready, Set, Self-Assemble

Big Fish, Little Fish is a cart demonstration that can also be used as a game focusing on what biomagnification is and how it happens in our ecosystems. *Ready, Set, Self-Assemble* is a full-body program that introduces participants to the concept of self-assembly in a fun and energetic way.

BACKGROUND AND GAMEPLAY

Nanoscale science, as with many STEM topics, includes phenomena that are hard for learners to visualize. The Network created many simple demonstrations and models to give visitors a peek into these phenomena, but sometimes there is no better way to explain the basic scientific rules at the nanoscale than through a game that gets learners up and moving.

Big Fish, Little Fish starts with a model of how nanosilver particles may bioaccumulate in organisms up through a food chain. Using metal BBs, facilitators show how a larger plastic fish will quickly collect nanosilver if they eat multiple smaller plastic fish containing BBs. This idea is further explored in a game that resembles tag or shark and minnows, which requires at least 10 participants. The players are assigned as a big, medium, or small fish and given two silver stickers to represent nanosilver. Larger fish can "eat" smaller fish by tagging them. When smaller fish are eaten, the players hand over their silver stickers to the bigger fish that ate them, and sit down. Eventually, only a few big fish will remain, each with a giant collection of silver stickers showing the effects of bioaccumulation.

Ready, Set, Self-Assemble uses a set of rules to govern a full-body model of a nano phenomenon known as *self-assembly* in a fun and energetic way for a group of players. Self-assembly is a process by which a group of components form themselves into functional organized structures through simple interactions. Self-assembly often occurs in nature: snowflakes, soap bubbles, and DNA are just three examples of things that self-assemble. In *Ready, Set, Self-Assemble,* groups form increasingly complex patterns by following rules about how they join hands.

These games get players moving around and interacting with each other in silly ways, adding a sense of play to museum programming. Players work cooperatively as a group to accomplish something they could not do on their own. Both games are followed by a discussion on the impact of these nanoscale phenomena on the natural world and our society, allowing players to reinforce the learning they experienced during the game.

OUTCOMES AND LESSONS LEARNED

Full-body learning experiences are known to have a positive influence on many types of educational programs (Abrahamson & Lindgren 2014). Watching and feeling your body move is a good

way to realize intricate steps of a complex process. In these games, the details about how a model works can become more significant when they are used to frame how players must interact with others in a novel social setting. Gentle peer pressure and a sense of teamwork are both serious motivation factors to quickly learning rules in group games. No one wants to be the molecule out of line while assembling!

These two games can also act as extensions and explanations for more traditional demonstrations in museums that reveal observable science phenomena. In *Big Fish, Little Fish,* the game reinforces the idea of how a contaminant can quickly spread in a living ecosystem. *Ready, Set, Self-Assemble* helps to strengthen understanding of the assembly steps described in two other NISE Net hands-on activities: *Snowflakes: Nano at Its Coolest* and *Exploring Fabrication–Gummy Capsules.* In the related demonstrations, visitors see macroscale results of phenomena and learn about models explaining those results. Pairing these demonstrations with the full-body games can make these models clearer, literally moving visitors through the process step by step. In this way, they help visitors fill in the gaps between what they can see at the macroscale and what scientists say is happening on the nanoscale.

LESSONS LEARNED FROM DEVELOPING AND IMPLEMENTING FULL-BODY GAMES:

Periods of physical activity can re-energize young visitors during a long program. Sometimes a movement game like *Big Fish, Little Fish* can wake up visitors and get them ready to participate in more learning activities. This is particularly valuable in classroom-style settings.

The emotional reward that comes from succeeding in a cooperative game is powerful. Succeeding as a group can be great motivation for participants and prepare them for more tasks and activities that require teamwork.

Full-body games can be low cost, requiring few materials. Apart from instructions and an energetic facilitator, there is usually not much else needed to run these types of programs.

VARIATIONS ON FULL-BODY GAMES

- **Alternative version for professional development training**

Improv exercises have become a popular icebreaker tool at many professional NISE Net meetings. Using improv also helps create a supportive and upbeat environment for educators to practice and strengthen positive learning conversations with visitors. One fun improv exercise example is a massively scaled version of Rock, Paper, Scissors that resembles the self-assembly game.

Participants are asked to pair up and play one round of Rock, Paper, Scissors. The loser of this game then becomes a cheerleader for the winner, shouting their name in glory, as the pair seeks out another pair to battle. Once the winner of this next game is declared, the loser and the cheerleaders now all shift to shouting the new winner's name. This continues until the group has self-assembled into two giant cheering sections each shouting one of the finalists' names for an ultimate Rock, Paper, Scissors mega-match. Not only is this a great way to demonstrate self-assembly and get people on their feet, it's a fun way to learn a few new names in an unfamiliar group.

2) Familiar Games as Models

One of the most helpful phrases a facilitator can hear from a young visitor as they start to present an activity is "I know what this is!" Familiar experiences are a great way to invite visitors of all ages to learn more about STEM topics and occasionally surprise them with unexpected results.

With educational programs using gameplay, it saves time and energy when visitors recognize the framework of a gaming experience and already know the basic rules. Young visitors often know what to do right away. When they don't, parents usually feel more confident in their ability to guide their children through a STEM learning experience with a recognizable game compared to ones without. Furthermore, when using easy, familiar games, educators and visitors can avoid falling into the trap of "learning to play the game" as the primary learning objective of the shared experience.

Prior knowledge and self-confidence associated with familiar surroundings is a long-known component of motivation in designing learning experiences (Keller 1987). NISE Net program developers capitalized on this fact by modeling several STEM learning experiences on popular game formats. In this section we will review NISE Net products adapted from well-known gaming sources including: (2a) *I Spy Nano* and (2b) *Nanotechnology Spin-a-Prize.*

2a. I Spy Nano

I Spy Nano is a fun and fast-paced game in which players try to find nano-related objects on a game board. Players learn about the different ways nano is found in the world around us.

BACKGROUND AND GAMEPLAY

Early front-end evaluation efforts in the Network showed that learning about real-world applications was a key motivator for sparking interest in nano among visitors (Flagg 2005). NISE Net program developers wanted to create an experience that highlighted these connections in an engaging way. *I Spy Nano* is based on a traditional game, with many variations in books and board games, where players scan and search for objects among a sea of possibilities.

Up to six players (or teams) compete to find nano-related objects. Each player gets a playing board with a colorful variety of objects. The facilitator reads a playing card with a statement about nano (e.g., "Some nanotechnologies are inspired by nature.") and then flips it over to reveal six images connected to the statement. Each

playing board has only one of these objects. The first player to find a matching object says "Nano!" and takes the card. The player with the most cards at the end of the deck wins. The objects and statements on the card often spark questions and further discussions about nano among players and facilitators.

OUTCOMES AND LESSONS LEARNED

Many people are surprised to learn that nano phenomena and structures have numerous connections to our everyday lives, and are found in both nature and technology. This is a fascinating message for public audiences, and can help them reflect on the growing role for nano and other technology in society. There is no doubt that *I Spy Nano* is a fun game for players. But beyond this, its clear objectives push participants to pay attention to the abundance and diversity of objects connected with nano.

Consider comparing this level of focus to a visitor reading a long list or passively viewing a video containing the same objects. The familiarity with the *I Spy Nano* gameplay and basic motivation of the players presented a greater opportunity for learning compared to a static display. Formative evaluation showed the phrases on the cards, connecting the objects to nano content, enhanced learning for some visitors. Even when the game was set out unfacilitated on the museum floor, parents, educators, and young visitors would read the words on a card out loud or use them to predict the objects before the card was flipped over.

An exhibit-sized variation of *I Spy Nano* was also included in the *Nano* small footprint exhibition. During testing, the graphic panel featuring the *I Spy* game was the most visited panel and the third most visited component in the exhibition (Svarovsky et al. 2013). Visitors also most frequently rated this graphic panel as having a connection to their own lives and experiences across all panels (Kollmann et al. 2015), showing the high level of personal relevance possible with the related *I Spy Nano* game used by NISE Net in NanoDays kits.

LESSONS LEARNED FROM DEVELOPING AND IMPLEMENTING *I SPY NANO*:

Museum games modeled on popular games may be so familiar that they don't need facilitation. During evaluation, many families and camp groups were observed using *I Spy Nano* with no museum staff present. When approached after their games, many visitors could articulate some of the nano content goals for the game.

Simple games are more likely to be remixed and customized by visitors. Visitors often came up with their own games using the *I Spy Nano* materials. For example, parents with very young children would use the game as an opportunity to point to and name objects.

Don't be afraid of fun. *I Spy Nano* may not be the most content rich STEM learning experience, but it has great potential to make an impact on players due to the fun and emotional reactions possible.

Games can be fun to play repeatedly. *I Spy Nano* also works well to fill time productively in summer camps and afterschool programs, because kids enjoy playing it over and over. Through time, they become familiar with the content messages and better at spotting the nano-related objects.

CASE STUDY:

I Spy Nano

Alan Brown
Sci-Port: Louisiana's Science Center, Shreveport

I used the *I Spy Nano* game in our Bars without Barriers program, a joint venture with the Caddo Parish Sheriff's Workforce Re-entry Facility. The program is composed of six classes with offenders on STEM topics and activities, each of which is followed by a supervised parent visit. We were excited by the opportunity to fold the NISE Net *Explore Science: Zoom into Nano* activities into our Science in the City theme.

The families were engaged with the *I Spy Nano* and *Powers of Ten* games in a prolonged, meaningful way, and the offenders specifically pointed out how much they enjoyed playing them with their children. That in and of itself is pretty telling based on the chaos that typically ensues during the family visits! There are many messy distractions among the kit materials, so it is always memorable when a simple activity with cards or a playing board stands out.

One of the goals of the Bars without Barriers program is to provide the offenders with tools and strategies that will allow them to reconnect with their kids. The STEM activities, beyond providing simple science instruction, provide talking points. *I Spy Nano* is perfect for that. Pictures of things like buses, soccer balls, nurses, pirates, pencils, and so forth are the perfect entry points back into the life of a child. They may not talk about how pencils use nanotechnology, but the fact that the eyes of both parents and children would be opened up to the technology that goes into (or is inspired by) everyday objects is a significant bonus on top of social interaction that the game promotes.

I think one of my more surprising insights after using the games would be the fact that I had totally forgotten the important role games played in my own education. I am quick to credit games like Monopoly® and Yahtzee® for the fluidity with which I process numbers, odds, etc., I am quick to credit games like Stratego® and chess for my ability to attend to detail, and I am quick to credit Scrabble® for the fact that my vocabulary is big and good. I would equally credit games for fostering the soft skills essential to proper socialization. It only makes sense that integrating games into a program like ours would serve the twin goals of Bars without Barriers.

2b. Nanotechnology Spin-a-Prize

Nanotechnology Spin-a-Prize introduces players to the basics of nano through a gameshow format. Participants learn that nanometer-sized things are small and often behave differently than larger things do, and that work in this emerging field leads to new knowledge and innovations. Players also consider the ways that nanotechnology will affect our lives.

BACKGROUND AND GAMEPLAY

The Network experimented with a variety of ways to engage public audiences in learning about complex concepts, including games. *Nanotechnology Spin-a-Prize* is modeled on popular gameshows where contestants receive a random number of points after they answer a question or solve a puzzle.

The game is simple. The "host" divides players into two groups and then presents a series of slides that contain all the answers to the nano-themed questions they are about to ask. A representative from Team 1 spins the wheel before the entire team answers a true or false question. A volunteer scorekeeper makes a note of the score, and then Team 2 takes their turn. There are about 10 slides and questions in each of the two game rounds. At the end of the game the scores are tallied, and everyone receives a small prize.

OUTCOMES AND LESSONS LEARNED

A great attractor for this game is the prize wheel itself. A wheel on gameshows is an iconic symbol and having it included with *Nanotechnology Spin-a-Prize* helped facilitators communicate key details of the gameplay immediately. Another success factor in this game is having an energetic host. Using teams, and a dynamic facilitator, to raise the level of excitement for everyone involved is a great way to increase the impact of learning experiences with gameplay.

The gameplay format of *Nanotechnology Spin-a-Prize* levels the playing field for visitors. The host presents the relevant information right before the quiz portion of the game, so regardless of their awareness of nano coming into the experience, all visitors are equally prepared for the quiz questions. Furthermore, team members consult with each other before selecting their answer, so no single person is put on the spot.

Even the low level of competition in *Nanotechnology Spin-a-Prize* helps players focus on the nano content necessary to score points. When compared to other NISE Net stage presentations featuring a range of demonstration styles, this game had the highest percentage of visitors reporting that the program had a high influence on their awareness of nano during formative evaluation (Onkka et al. 2009, based on a version of the game known as *Wheel of the Future*).

LESSONS LEARNED FROM DEVELOPING AND IMPLEMENTING *NANOTECHNOLOGY SPIN-A-PRIZE*:

Competition can be fun and motivate visitors to learn, but consider ways to soften the edges. Equalizing content delivery, letting players collaborate, and integrating an element of random chance is a good way to avoid the creation of sore feelings among players. NISE Net educators also recommend that if there are prizes, they're given to all participants.

Facilitator energy level is sometimes critical for a fun learning experience using games. Adding games is not always an automatic enjoyment boost, and can be highly dependent on the skills and approach of facilitators. To successfully run some games for large groups (especially a gameshow-like program) facilitators need to be high energy.

Don't discount the power of popular culture. Gameshows may seem silly, but they represent shared knowledge for anyone that has spent a few hours channel-surfing. This awareness is something museums can easily leverage for attractors and interest across many learning experiences. Having a lower barrier to entry in terms of basic gameplay and rules is essential for most games at museums.

"Nanotechnology Spin-a-Prize has become an indispensable tool to introduce nano in our outreach events. We have found that special education students enjoy this game and appreciate the fact that they can participate along with students from the regular track."

– Idalia Ramos, University of Puerto Rico, Humacao

A BLAST FROM THE PAST!

StretchAbility

Our childhood memories are chock-full of dramatic victories and defeats while playing classic board games. Many of these games can be a source of inspiration for new learning experiences in museums. *StretchAbility* is a fun, hands- and feet-on game that explores objects on several different scales. Just like another well-known body-twisting game, players take turns placing their hands and feet on colored dots determined by a spinner. In this case, the colors are associated with nano, micro, or macro scales, and each dot contains a representative object at the assigned scale. The game works well for whole family groups, and young players are thrilled when their parents join in the silliness and fun. While it may result in some unusual body contortions for a museum floor, *StretchAbility* is an enjoyable way for visitors to be introduced to the visual differences of objects across the three scales. The game is also a great conversation starter for facilitators and visitors, and can spark further interest in the strange world at the nanoscale.

3) Creating Gaming Challenges for Young Visitors

Although many of the games already discussed may work or could be modified for younger visitors, NISE Net program developers created several short experiences specifically for this age group. Many partner museums in the Network serve family groups with young children, and NISE Net has made significant progress in recognizing and addressing the needs of children's museums in educational material development. The examples shared here use the surprise and wonder of objects at the nanoscale to stimulate interest in young children. While these activities are not full-fledged games, they use game-like elements that help make the challenges feel playful.

3a. Horton Senses Something Small

In the *Horton Senses Something Small* story time program, young visitors listen to the Dr. Seuss book *Horton Hears a Who*. Following the story, they look at small things with lenses and use their sense of smell to detect things that are too small to see.

3b. What am I? Mystery Cards

For this simple guessing game, visitors flip between macro and nanoscale images of familiar objects. They learn about ways that nanotechnology is inspired by nature, surprising properties at the nanoscale, and new applications in nanotechnology. After the game they can choose a card to take home.

BACKGROUND AND GAMEPLAY

Both of these examples have a core experience of a guessing game. In *Horton Senses Something Small,* visitors learn that nanoscale particles cannot be seen but they can sometimes be detected by the sense of smell. Visitors listen to sections of *Horton Hears a Who* and learn about the elephant that can hear very quiet sounds that other animals can't hear. To further draw children into the story, visitors wear paper elephant ears throughout the program. After using a lens to look at small things, they investigate a series of balloons with scents inside. The children guess what smells are coming from each balloon and match them with pictures. Facilitators help guide parents and children to think of their own noses as sensitive detectors that can recognize tiny scent molecules they cannot see. At the end of the program, each child receives a scented sticker prize.

What am I? Mystery Cards is even a more modest activity. Each card is a riddle showing a photo of an object at the nanoscale with a giant question "What Am I?" printed on the front. Visitors try to guess what the object is before they turn over the card to see a more recognizable photo of the object at the macroscale, revealing its identity.

OUTCOMES AND LESSONS LEARNED

Using a story is a great way to add context and stimulate visitors' imaginations. *Horton Hears a Who* introduces children to the idea that there is a world that is too small to see that we can investigate with our senses and tools. The hands-on activities following the story allow young learners to develop and apply their investigative skills in an age-appropriate format.

While short and simple, guessing games can captivate the attention of very young children and spark conversations and questioning. Although many visitors can't guess the answers, they enjoy the surprise of discovering that a mysterious nanoscale structure is related to a familiar object. This surprise prompts closer investigation of the nanoscale image, and allows the facilitator to help them interpret it and understand its significance.

LESSONS LEARNED FROM DEVELOPING AND IMPLEMENTING GAMING CHALLENGES FOR YOUNG VISITORS:

All around the world, children learn through games. In all societies, at all times, children have played games to help them learn about themselves, the natural world, and their culture. STEM education can take advantage of the power of games to integrate people, culture, and nature.

Storytelling and games are a natural fit. From *Clue®* to *Super Mario Bros.®,* traditional and digital games often have a narrative and pretend world that sets up their objective and makes play more engaging and compelling.

Take-home materials can extend learning. The take-home *What Am I?* cards give visitors a memento of their NanoDays experience, which later can be shared with someone else and invite the previous young player to become the expert.

Guessing games build and reinforce skills. Guessing games incorporate observation, recognition, identification, and matching skills. These games take many forms, can use different senses, and are designed to be easily played repeatedly by making slight changes to the content.

WHAT'S IN THE BOX?

Mystery Shapes

Mystery Shapes is a hands-on activity in which visitors use their sense of touch to investigate hidden objects. Visitors put their hand in a box and try to draw what they feel inside without peeking. This challenge of trying to draw and identify an object based on tactile information is similar to the way researchers use scanning probe microscopes to make images of nanoscale objects. The guessing game can be played over and over again with young visitors, who enjoy guessing different hidden objects. Not many activities developed by NISE Net depend on touch, adding variety to the kinds of experiences that are offered at NanoDays events. Visitors also learn there are some characteristics of objects that cannot be determined by touch, such as color. This presents a good learning opportunity about how scientists use multiple senses and different tools to gather data about the unknown.

Conclusion

This guide features a handful of NISE Net's experiences with gameful approaches to STEM educational activities. Many more products using games are available in our online library, ***nisenet.org***. Here, we have tried to capture some of the general development and implementation strategies for games that can be widely applied to learning experiences for informal settings.

We believe games can be powerful tools for learning, and inspire strong connections between people and content. But you don't have to take our word for it; try the following game with some colleagues and find out for yourself:

"I Say Hi!– Gaming Edition" Improv Exercise

(Adapted from "I Say Hi!" developed by Museum of Science and Industry, Chicago)

This is a great exercise to help build personal connections, generate positive energy between team members, and learn something about NISE Net's experience with gaming. The group repeats a simple rhythmic pattern as each person introduces themselves and their "friend" standing next to them in the circle. "1...2,3,4,5. My name is (name) and I say Hi! 6…7, 8,9,10. This is (name) and s/he's my friend." Participants then share three fun facts about their new friend related to games as the rhythmic pattern continues around the circle.

Skill sets

Teamwork, Listening/Awareness, Energy

Time to implement

8–12 minutes

Number of participants

8–12 in each group

EXERCISE FLOW

1. Ask the participants in the group to stand beside someone they don't know very well.
2. Have the group briefly introduce themselves to the person on either side. Tell them their task is to learn about their partner's favorite game to play with others, in the past or present.
3. Explain that in the exercise one person will introduce themselves and their friend to the group. The full group will support through a simple rhythmic pattern.
4. Introduce the rhythmic pattern to the group.

    Group: One…two, three, four, five!

    Focus Person: My name's _____ and I say hi!

    Group: Six…seven, eight, nine, ten!

    Focus Person: This is _____ and she's my friend! Her favorite game is _____.

5. Have the group practice the first portion of the rhythmic pattern together. Use your own name and introduce the person standing to your side.
6. Introduce the second part of the rhythmic pattern to the group. Explain that the person gives three phrases about why their new "friend" likes their favorite game. The group will call for the phrases by counting together. Give an example; in this case the favorite game was charades.

    Group: One!

    Focus Person: She likes to draw.

    Group: Two!

    Focus Person: It is fun to laugh with people.

    Group: Three!

    Focus Person: She has good memories of winning with her sister.

    Group: Four! Four! Four! Four! One…two, three, four, five!

7. Have the group complete the entire pattern once together. Ask if anyone has any questions.
8. Explain that the pattern repeats as the "friend" becomes the next person to give an introduction. Continue around the circle until everyone has been introduced.
9. Stop the exercise and quickly debrief. (If time allows, try the observation/conversation variation.)

DEBRIEF QUESTIONS

1. Who learned something new about someone? What was one new thing that you learned about a team member?
2. Who found they had a favorite game or reason in common with someone else? What was it?
3. What were some general categories for the reasons for liking games that came up from the group, such as social aspects, childhood memories, or emotions?
4. How could we use the game characteristics we learned from this exercise to help us better engage visitors to our museum?

TIPS

Encourage the group to stay in the rhythm of the song/chant while giving descriptive phrases. Emphasize that descriptive phrases can be anything and creativity is encouraged.

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