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SPECIAL REPORT

The KC EMPOWER Project
Designing More Accessible STEM Learning Activities

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BLAMING THE LEARNER

Imagine listening to a lecture during which the speaker used technical jargon you couldn't begin to understand; Or playing a computer game with seemingly arbitrary rules that resulted in your avatar dying so quickly that you could barely get started; Or trying to gain access to a product through packaging that could withstand a bomb blast.

Most of us regard these as problems of *accessibility*: the speaker or designer had a fundamental misunderstanding of the audience and therefore placed unrealistic expectations on them.

But imagine if someone were to offer an alternative explanation: you are the problem. You are broken and incapable of understanding language, playing a game or opening a package. In that case, you would probably be offended and argue that there was nothing wrong with you. However, if other people agreed with this alternative explanation, suggesting that the problem was not the lecture/game/package, but rather *you*, and your feeble brain, slow reflexes and weak body, you might eventually accept this explanation.

Would you then be eager to engage in new learning opportunities and take on new challenges? Or would you default into a state of disengagement with a world that seemingly didn't need or even tolerate your participation?

This exercise gives you just a taste of the challenges endured by people we might call the "disabled labeled." Even though the frustrations of inaccessibility are familiar to all of us, we nonetheless create a dividing line separating people we consider "able" and those who are not. But in reality, there is no such line. There is no "disability" and "ability"—there is just variability. Each of us accesses, understands and shares knowledge differently.

It's bad enough when poor design excludes people from public events, computer games and packaged products, but it's worse when such inaccessibility is found in educational activities, thereby excluding many children from rich learning experiences. It's worse still when those activities focus on STEM understanding, an area critical for success in the workplace and for navigating an increasingly complex world. Missing out on such learning opportunities can be catastrophic for individuals and detrimental to society as a whole.

This paper is about our effort to examine how STEM resources could be made more accessible for students, regardless of what abilities they bring to the table. We looked at a small selection of afterschool STEM activities taken from 80 that we developed 15 years ago, through a previous National Science Foundation grant (Award # 0104671, *Kinetic City After School: An On-line Adventure*). Though the original project revolved around a story that was told online, most of the activities were hands-on. Our new look at the activities included one computer game and four off-line activities. Supplementing our discussion of the project in this article is a formal report on the work, included as an appendix (Moeller and Martin, 2015. *Kinetic City Empower: Research Report*).

UNIVERSAL DESIGN IN STEM LEARNING

The term *Universal Design* has been in use since the 1980s to refer to architecture and product design fostering accessibility for the widest range of people. The emphasis is on designing accessibility into the product or building right from the start, rather than adding accommodations for users with particular needs.

Since the 1990s, David Rose and colleagues from the Center for Applied Special Technology (CAST) and others applied the concept to education, with the *Universal Design for Learning* (UDL) framework. UDL is not focused on creating sets of new resources designed specifically for people with particular disabilities—a sort of "separate but equal" solution. Instead, it focuses on how to create learning activities for everyone. Key principles are that the activities should provide multiple means through which learners engage with the activity, ensure that any materials and/or knowledge required to participate in the activity is presented in a variety of ways (including alternative representations of auditory and visual material) and that learners are allowed different ways to demonstrate and share their knowledge.

The vision is that all learners can participate in UDL-based activities without requiring significant additional assistance from human or technological helpers—just as all people should be able to access ADA-compliant buildings without the need for assistants to hoist visitors out of their wheelchairs to carry them upstairs, or the purchase of expensive stair-climbing wheelchairs.

However, few learning activities now employ UDL. The emphasis is on special education specialists, who must take restrictive activities and environments and wrestle them into a form that will allow children with special needs to use them. This is much less effective than designing activities and spaces to be inclusive from the start. To be clear, we are not suggesting that UDL-based activities replace or diminish the role of educators, but rather that they provide educators with resources free of unnecessary barriers to learning.

KC EMPOWER

As part of a two-year NSF Advancing Informal STEM Learning (AISL) Pathways project, we examined what UDL would mean for developers of science activities. These are the thousands of games, demonstrations, hands-on science activities, art/music/social studies "blended learning" resources, and other educational activities, often developed through grants from NSF and other public and private funders, and shared widely through a variety of STEM education web portals.

The vast majority of these activities require that children see, walk and read visual text. To the extent that they can be used by children who are blind, or who use wheelchairs, or who have other differences, they require adaptation by educators—this despite over a decade of research showing that learning activities can be designed to be accessible to a wide range of learners, and that all students benefit from activities designed in this way.

There are many possible reasons why UDL principles are so rarely implemented. Perhaps incorporating them is simply too difficult under the tight time and money constraints of activity developers. Perhaps they are particularly difficult to implement in a STEM learning environment, possibly because of unique attributes of STEM-based activities. After all, STEM, more than other content areas, requires precise measurements, careful observations and the use of specialized tools, instruments and materials. It's possible that these factors make STEM UDL-proof. That could explain the paucity of UDL-compliant STEM resources.

For this project, we wanted to see how difficult it would be to develop activities that followed UDL principles, and whether making those changes would make the activities better or worse for general use. Therefore, the *KC Empower* project staff, advisors and researchers selected sample activities, tested them with kids that had different special needs, got feedback from the kids and the adults who worked with them, and then reviewed what we discovered with our advisory board, consisting of some of the top experts in accessibility and learning issues.

Then, based on these tests and recommendations, we made changes to the activities and tested them again with our target populations to see if the changes made them more accessible and effective. We took special note of overarching issues and design ideas that could prove useful for others working in the field.

While UDL was originally developed with an emphasis on new technologies and how they could broaden access to learning, our goal was to use technology only as one of many routes to improve access, and then only if the technology is widely available, easy to use and inexpensive. We didn't want to erect new walls of cost and lack of availability in our effort to remove walls related to usability and access.

Throughout the work, we strove to be respectful of all the work that had gone into creating the large library of STEM resources now available. Before concluding that an activity had to be completely redesigned or replaced, we'd look into less drastic changes that would provide a solid return for a small investment in time, energy and money. In an ideal world, every resource would be designed for wide accessibility right from the start. In the real world, NSF and many other funders have made an enormous investment in the creation of tens of thousands of activities, and it behooves us to look first into how those resources can be improved, rather than replaced.

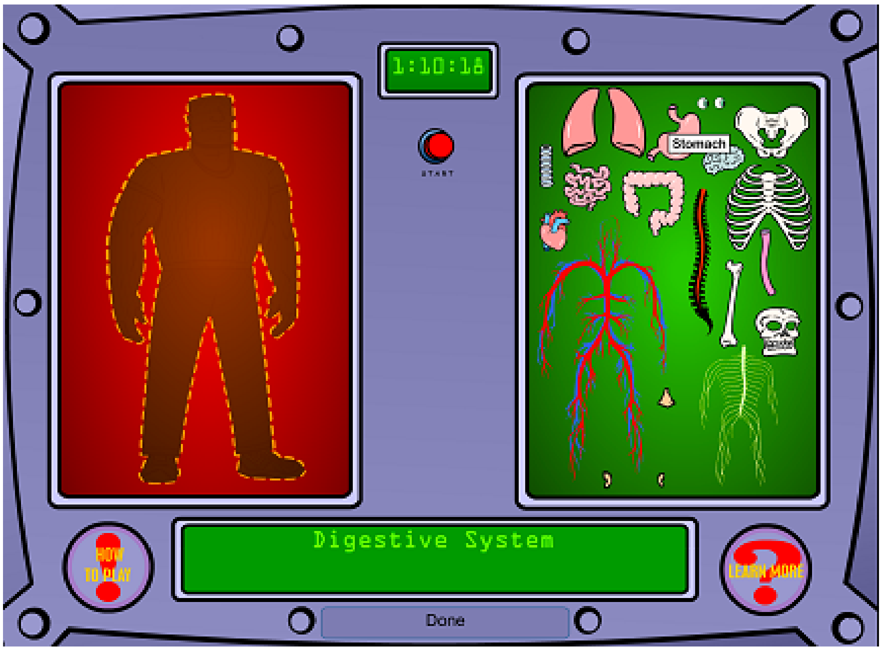
THE FIVE TEST ACTIVITIES

We focused on five sample activities, which we took from our Kinetic City After School project. This was an NSF-supported program that took 16 different science content areas from *Benchmarks for Science Literacy* (AAAS, 1992) and offered five informal science activities for each: a computer game or simulation (called a *Mind Game*), a traditional hands-on science activity (*Fab Lab*), a phys ed style activity (*Move Crew*), an art activity (*Smart Art*) and a creative writing activity (*Write Away*).

ALL SYSTEMS ARE GO

All Systems Are Go is a *Kinetic City Mind Game* in which a regularly occurring Kinetic City character, Arnold Rutabega, has lost his internal organs. Students are asked to retrieve them, one system at a time. A "Learn More" button brings up a text essay on the major systems of the human body, describes the organs and other parts in each system, and explains how they work together to accomplish a job. Arnold asks for his organs back not individually, but by system, as in "I feel breathless and heartless! Find my circulatory and respiratory system!" and "Now I feel like nothing's holding me up; find some important parts of my skeletal system." A timer runs during game play for children who want to play repeatedly to improve their time, but there are no points or time limits.

Like many computer games designed in the early 2000s, *All Systems Are Go* was created in Adobe Flash, the early versions of which had few accessibility options. Specific issues identified during our testing included lack of any accessibility features for blind users and strong reliance on fine motor coordination using a mouse interface. In addition, some children were confused or displeased with the lack of object permanence: organs correctly selected and placed in Arnold's body would reappear as potential selections in subsequent screens. This was originally done so that the screen didn't gradually run out of selections, such that the final body system had no "wrong" organs left. However, in our testing, some of the children objected to this lack of logic, as well as Arnold's ability to engage in conversation despite missing vital organs.



SUGGESTED REVISIONS:

After reviewing the results of our play testing with children and input from teachers and parents, our advisory board and staff had a long list of potential changes to *All Systems Are Go*, focused primarily on accessibility issues. Some of these issues are native to the Flash platform and, since creating a new game in a different platform was beyond the scope of our project, we weren't able to perform that subset of the suggestions as optimally as we could have in a completely new game.

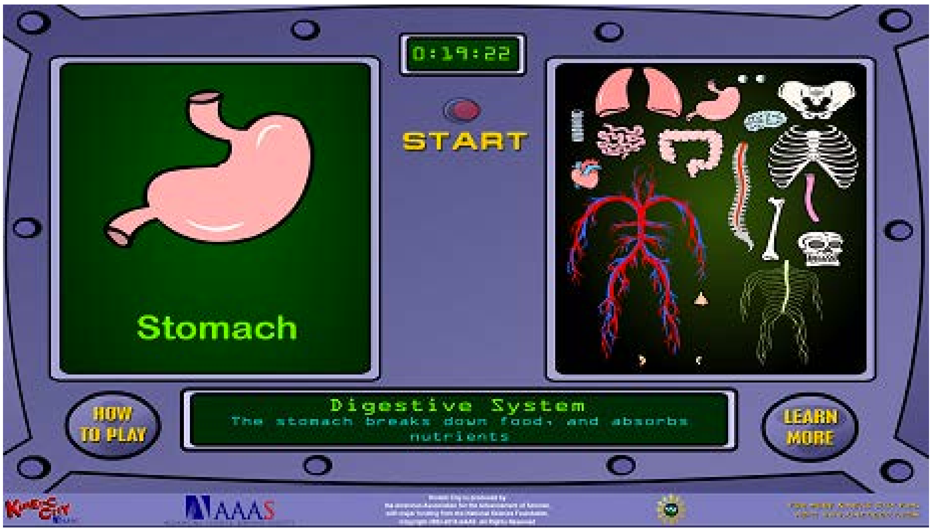
In addition, there were suggestions of basic changes to the game design itself—for example, making the player an actual doctor diagnosing a patient. These would have entailed creating a new game as well.

The revisions that we undertook for this activity were:

- Make the game fully keyboard accessible, in addition to mouse accessible, so blind children and children unable to control a mouse can play;
- Add audio for all buttons and selections; add narration for “How to Play” and “Learn More”;
- Make all possible selections into buttons that can be accessed by the tab button and selected with the spacebar or enter key;
- Use “shift-tab” to move through selections backwards;
- Start game with cursor at top; spacebar should trigger “Start Game”;
- Add a visual indication of keyboard focus;
- For game play, put keyboard focus on any body part, beginning with top one; then use tab or arrow keys to highlight each organ and play audio;
- Return key or space bar selects organ highlighted;
- Add a way to show large versions of each organ selection, for low-vision players;
- Enhance screen contrast for low-vision players;
- Give the organs in the game “object permanence”—for example, when an organ was dragged from one screen to another, there was never a re-occurrence of that organ in the screen from which it was dragged.

ALL SYSTEMS ARE GO REVISED

We were able to implement all the changes in the bulleted list, except for adding the two low-vision enhancements (large versions of each selection appearing and screen contrast changes), which weren’t complete until after our site tests due to technical issues with the old Flash code. The new version of this activity, which will replace the current version now in use, has all of the enhancements.



DISCUSSION:

Overall, the adaptations we made to this activity improved both access and engagement for children.

The key changes that were made in the game (offering an alternative to the drag and drop feature for moving the organs, providing audio labels for the organs, changing the *response that students got when they make a mistake, removing organs that have been placed from the right side of the screen) were successful for improving the physical accessibility of the game and students' cognitive engagement with it.*

– EDC CCT "Kinetic City Empower Research Report" (See Appendix)

It should be noted that audio features of the game did not trigger unless a player first attempted to play using keyboard control, indicating low vision. Since we found that many sighted users also appreciated the narration, and we know that many students struggle with reading, future versions of the game should include a toggle switch to turn audio on and off. Also, since so few games allow full keyboard control, and educators in many settings are not aware of computer accessibility options, the game should add information for educators, telling them about the game's accessibility features, and also about the importance of activating the Universal Access option in their computer preferences or control panel.

Changing the game such that each object on screen occurred in just one place at a time meant that as players progress, there were fewer and fewer organs from which to select, and by the time players reach the last system, all of the selections are correct selections. In future versions of the game, we could add more distractor items and/or vary the order in which the organ systems are requested. Also, we found that when children play the game rapidly, the audio files play on top of each other. Future versions should cut off each audio file more quickly when the player changes the focus of the cursor.

We were surprised at how easily and inexpensively the accessibility features could be added to *All Systems Are Go*, especially since they weren't original to Flash, and had to be programmed into the game. We were also surprised how well and how seamlessly they worked. Like many educational game designers, we were skeptical about the feasibility of making such a visual game accessible to blind users, and concerned that providing the option of tab- and click-based play, as well as drag and drop, would make the game too easy. But students can self-select the mode that works best for them, and know enough to choose based on how much fun it is, rather than how quickly it allows them to finish the screens.

We were also surprised to discover that the changes enhance the game for children who are not blind and who do not have difficulty with the computer mouse, as well as for those who do. All children benefit from having the game's text augmented with narration, especially since the game has several hard-to-pronounce names and terms. None of the changes stand out to the player as accessibility modifications; they just make the game experience richer.

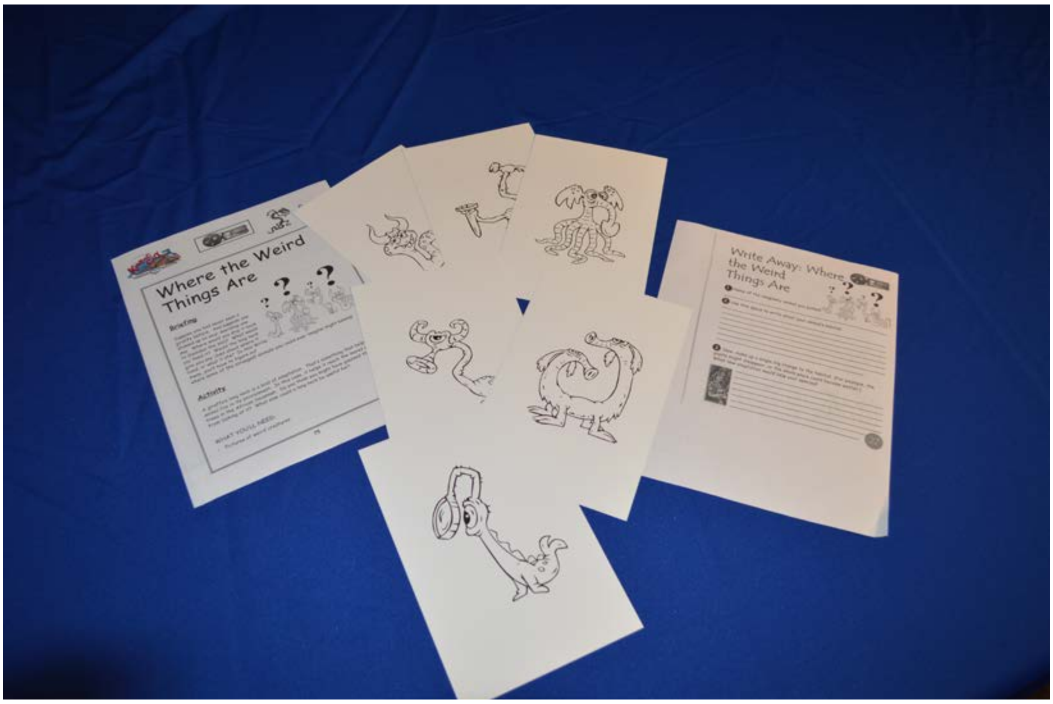
The Flash animator who worked on the graphical changes had never experienced a Flash game with full keyboard control, despite having worked in the business for over fifteen years. Regarding the project, he wrote, "I would never have imagined that this type of educational game could be adapted for full keyboard control, but have been amazed by the result. It would be difficult to approach my future work without taking the possibility into account." The fact that *All Systems Are Go* could be so easily converted, despite being a purely visual game, highlights the potential for this sort of retrofitting for virtually all learning games.

It should be noted that we did not make story-based changes to the game suggested by some children in our learning disability group, partly because they were more extensive than we could afford, and also because we were unsure whether they would improve the game. The children pointed out that Arnold should, by all accounts, be not merely dead, but like the Wicked Witch of the East, really, most sincerely dead. And how was he able to talk if he had no organs? Further research could look into whether or not games requiring "suspension of disbelief" impede engagement with this user population.

As a follow up to this work we will disseminate a step-by-step guide to making learning games fully keyboard accessible, and outline additional design options to enhance accessibility without degrading game play.

WHERE THE WEIRD THINGS ARE (YOUR CREATURE'S FEATURES)

Where the Weird Things Are is a writing activity in which students are shown pictures of six strange beasts and asked to make up a story about one of them that describes where the creature lives and how its strange features help it survive there.



SUGGESTED REVISIONS:

Our Advisory Board suggested the following revisions:

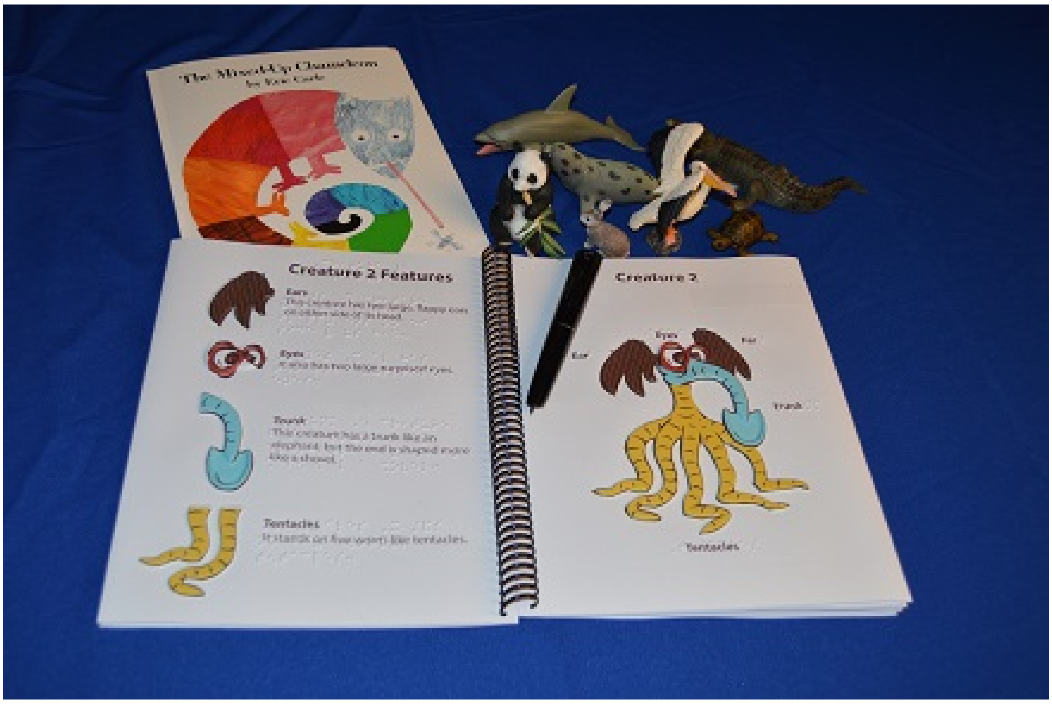
- Render the beast drawings in raised ink or 3D, so low-vision kids can feel them;
- Add words to describe them, too, like "has two short horns on its head and a long tail shaped like a corkscrew" along with audio descriptions;
- Consider adding speech recognition software so that kids can dictate their responses rather than write them;
- Have some plastic realistic animals on hand so that kids can look at their adaptations and consider where those animals might live;
- Consider changing the name of the activity, since some children might be put off by the term "weird."

WHERE THE WEIRD THINGS ARE REVISED:

We made major changes to this activity to make it more accessible for low vision users, and more engaging overall. The original activity had just black and white line art. For the revised activity, we contracted with the Touch Graphics company to re-create the artwork as a book of 3D raised images, with colors and textures. In addition, each creature was divided into parts, like "head," "body" and "tail" and each of these parts had a text description, e.g., "This creature has a long tail with a spike at the end." The descriptions are provided in both letters and braille. Talking pens were programmed to read the descriptions out loud when a user holds the pen over a creature or a particular feature. Finally, we did change the title, per advisory board request: it is now called *Your Creature's Features*.

When presenting the activity to children, we put an assortment of plastic animals like porcupines and walruses on the worktable, and talked about how these real animals' features helped them survive in their environments.

We looked into acquiring speech to text software so that children could dictate their stories to their computers and have the computers save them as text files, but the available software required clear speech from a single user in a quiet environment, and therefore wasn't suitable for our team-based after school program. So we put this feature on the back burner until the technology improves.



DISCUSSION:

Your Creature's Features was a significant improvement over the original activity.

The students with learning disabilities said that they liked the Creature's Features book. They said that they got a better sense of the creatures because they are in color and had some descriptions. The students also liked that they could access the descriptions through audio or by reading.

– EDC CCT "Kinetic City Empower Research Report" (See Appendix)

However, with the addition of technology came some new problems, since some students had difficulty activating the talking pen, which sometimes remained silent if students didn't move it laterally, as opposed to tapping it on a feature. The manufacturer says they can make changes to the graphics that will make the pen more responsive.

Your Creature's Features is a great example of an activity that is much better as a result of our re-design process. When we approach a product with a new perspective—for example, from that of a blind child, or a child who prefers multisensory options—we come up with ideas we wouldn't imagine otherwise. Rather than adding constraints, the process unearths new possibilities. Many kids—not just blind ones—prefer tactile graphics. And adding audio opens up whole new options for humor and creativity.

In this case, we significantly increased the cost of producing the activity materials: design and production was $6000US, and included ten books and four programmed pens. But in large quantities, the cost of the tactile books was reduced substantially (to about $40US per book and $90US per talking pen). In the U.S., government subsidies are available for products that meet the needs of children with disabilities, making this technology more affordable. We would encourage any group designing activities with flat graphics to consider making them tactile and adding an audio component, especially if the program already includes physical objects and therefore already includes a means of distribution beyond the internet. In addition, with the cost of 3D printing dropping rapidly, a STEM program delivered via only the web could consider distributing files for 3D printing relevant objects, so that both sighted and blind children can hold and feel them.

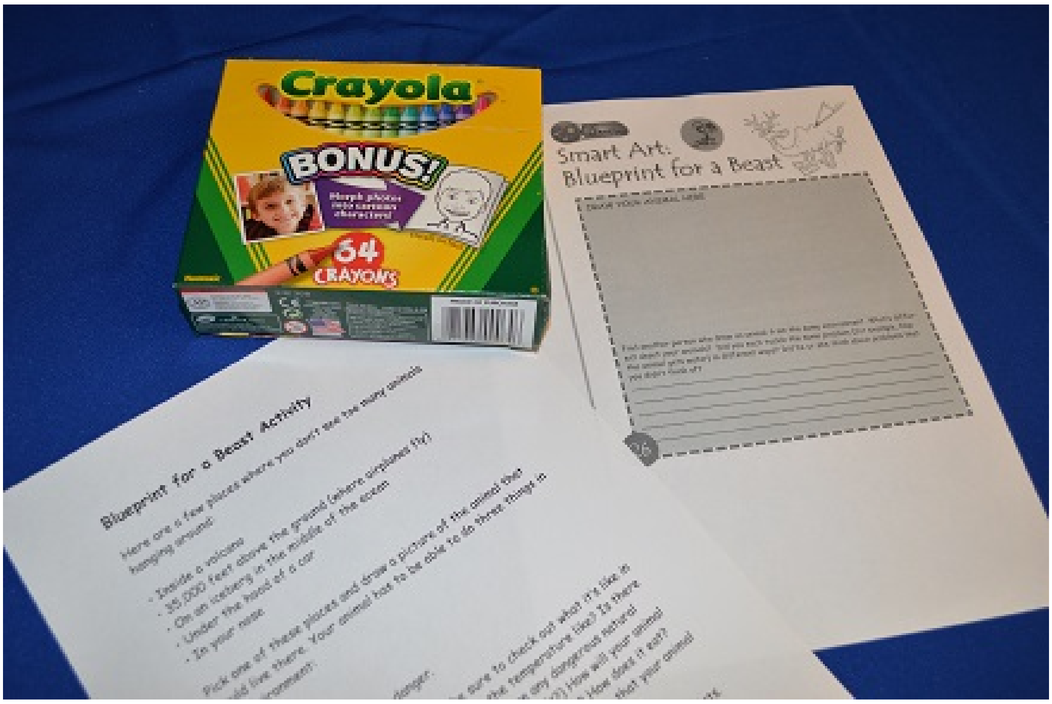
One unmet challenge with this activity is the lack of effective means to help children create and share their creature story. Few children wrote anything in the supplied journal pages, preferring to simply describe out loud what their creature ate, how it used its unusual features, and how it survived in its environment. Even during the original incarnation of these activities within *Kinetic City After School* groups, children wrote only sparingly.

One possible solution would be to add more scaffolding to our journal page, to help children structure their stories. We could also go further, turning the activity into more of a *Mad Lib*-style exercise, in which children fill in blanks in a story with words or phrases that demonstrate understanding and also allow creativity and humor.

Another, more ambitious, solution would be to create new digital interfaces that allow children to record ideas and observations and to produce documents and/or other means of communication without having to type on a keyboard. Such interfaces could work with computers, tablets or mobile phones. Many research laboratories at companies, federal laboratories and universities are exploring such interfaces for both business and military applications, and work has progressed sufficiently that it might prove worthwhile to explore the potential for UDL-inspired educational interfaces as well.

BLUEPRINT FOR A BEAST

Blueprint for a Beast is a *Kinetic City Smart Art* activity, and is a sort of companion activity to *Your Creature's Features*. But instead of being given a creature and asked to consider what sort of environment it might inhabit, students are given a habitat, and asked to invent a creature that could survive there. The environments provided are challenging: inside a volcano; 35,000 feet above the ground (where airplanes fly); on an iceberg in the middle of the ocean; under the hood of a car; or in your nose. Creatures must be able to move, drink and eat, and protect themselves from any dangers their environment presents. Students draw their creatures in a journal page with whatever art supplies are at hand.



SUGGESTED REVISIONS:

Our Advisory Board suggested the following:

- Add pictures of the environments to the instructions;
- Provide real life or fictitious examples of animals and their adaptations, possibly with a picture book like Eric Carle's *The Mixed Up Chameleon*;
- Rather than just draw the beast, maybe have them make it out of modeling clay or other easy to mold material;
- Have kids draw with something that adds dimensionality, like puff paint or Wikki Stix;
- Consider including animal parts, like tails, wings, fins, and horns that students can select from;
- Have the students create something they can take home with them.

BLUEPRINT FOR A BEAST REVISED:

For *Blueprint for a Beast*, we opened up the creative options with modeling clay, Wikki Stix, and a variety of other art supplies and papers, and had the students show and describe their creatures for the group. For one of our sites that included younger children, we began the activity by reading *The Mixed Up Chameleon* to the group, stopping to ask them about different characteristics described in the book and what each animal did with its adaptation. At both sites, students could take their creatures home with them.

DISCUSSION:

Neither the original *Blueprint for a Beast*, nor the revised version, were as effective as we expected.

> *The changes made in this activity (the use of the Eric Carle book, the supply of a greater variety of arts materials, asking students to share their animals with the group) met with mixed success. The greater variety of materials increased the physical accessibility of the task, but did not appear to increase the cognitive engagement with it. Girls appeared to be more attracted to both versions of the activity than boys.*
>
> *– EDC CCT "Kinetic City Empower Research Report" (See Appendix)*

We thought the creative, open-ended nature of this activity would make it the most accessible and easy to adapt of the five activities. The activity didn't explicitly require sight, hearing, or mobility. However, we had limited success in achieving engagement among our test groups. The most likely reason is that our groups all had a significant number of students with learning disabilities. Unlike *All Systems Are Go* and *Your Creature's Features*, this activity has no attention-getting graphics, audio, colorful objects or game play—it's purely creative and open-ended. Simply posing a challenge and offering an array of creative expression materials didn't sufficiently engage these children in the science content of the activity. It took effort by the educators in the room to motivate them.

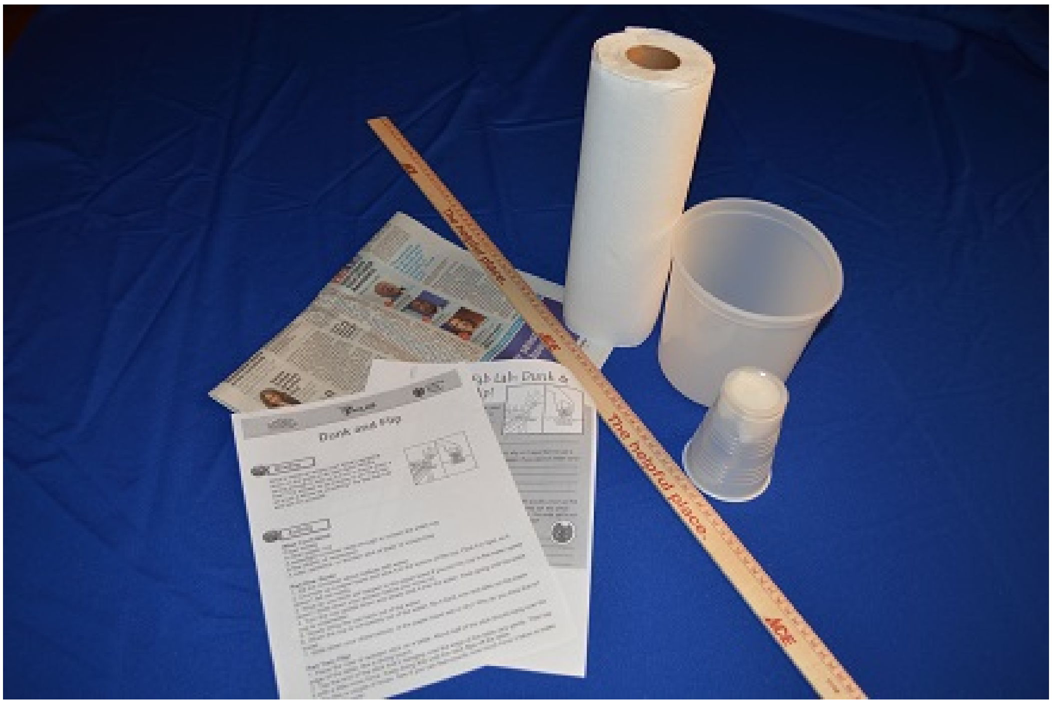
Future work on the use of artistic expression to enable children to share STEM-related ideas could look into creative assembly of objects, rather than creation from raw materials. This would add enticing, novel elements to the activity, offer students a quicker entry point, and could be especially useful for children who have difficulty working with standard art supplies.

For example, one of our contractors suggested creating a kit with a large number of magnetic creature parts that children could assemble, including heads, bodies, limbs and tails. Children would build a creature suitable for a particular environment. Technology might enhance this activity: the parts could interact with computer tablets, such that an environment could appear on screen, and players could assemble physical body parts on the screen surface. As with several products now on the market, these physical pieces would interact with the tablet, which would provide audio and visual feedback to the child. Rather than guide children to a particular answer, the information would encourage creativity and exploration. Developing such a product is one of several spin-off projects we are considering.

DUNK AND FLIP

Dunk and Flip is a *Fab Lab*, or hands-on activity, consisting of two demonstrations that focus on showing children that air has mass and takes up space. In one demonstration—the “dunk” portion of the activity—children secure a crumpled up paper towel into the bottom of a disposable cup, tip it over so that the open side faces down, and submerge it in a plastic tub of water. Before conducting the demonstration, they are asked to predict what will happen to the paper towel. Most students predict that it will get wet. Ideally, after conducting the demonstration, they see that the towel stays dry and suggest various explanations for the result, leading to the conclusion that air was already in the cup, taking up space, and prevented the water from entering. Therefore, air is not “nothing:” it can fill a space and its presence can preclude other stuff, like water, from taking up that same space.

The second demonstration involved placing a meter stick on a table with more than half of the meter stick extending beyond the edge. The kids cover the portion of the meter stick on the table with a large sheet of newspaper and predict what will happen when they press down sharply on the extending portion of the meter stick. They generally predict that the paper will fly up into the air. After trying it, they find that the paper is harder to push up than they predicted. They suggest various explanations, one of which could be that the paper is heavier than they thought. They then have the option of trying the same demonstration with a crumpled up sheet of newspaper on the end of the meter stick. It flies up into the air easily, as they originally predicted. They conclude that it is something about the newspaper lying flat and taking up a large area that makes it seem heavier. They learn that air has mass and is pushing down on everything; the flat newspaper has a larger surface area than the crumpled newspaper, so there’s more air pressure acting on it. That pressure makes the meter stick harder to push.



Children in our study group had some issues completing the hands-on activities. Securing the paper towel inside the cup and then turning the cup over and submerging it into the tub required considerable dexterity. If the paper towel wasn't sufficiently crumpled and jammed into the cup, it didn't always stay in place. Furthermore, since the cup was opaque, children couldn't see that the paper towel wasn't secured properly. The newspaper/meter stick demonstration posed a difficulty for children who use wheelchairs, who couldn't stand over the newspaper and smooth it down evenly. If the newspaper wasn't completely flat, the demonstration wasn't effective.

Overall, it should be noted that demonstration activities like these depend on facilitators to engage children and help them perform the activity. The children showed little interest in the materials until the facilitator jumped in energetically to engage their attention and demonstrate the procedure.

SUGGESTED REVISIONS:

Our Advisory Board suggested the following:

- Use all clear parts for dunk portion of activity, rather than paper cup and translucent tub;
- Consider replacing tub and cup with large soda bottle, cut in half;
- Secure paper towel with the bottle cap;
- Add food coloring to allow children to see more clearly;
- Replace newspaper "flip" portion of activity with something else that demonstrates that air has "substance";
- Possible replacement: place table on plastic bags or balloons and inflate to lift table.

DUNK PORTION OF DUNK AND FLIP REVISED:

We implemented and tested the suggested changes. The resulting soda-bottle based apparatus was a bit larger and easier to manipulate, was clear, so that children could observe what was happening in the cup, and would allow children to secure the paper towel with the bottle cap, so it wouldn't fall into the water. In practice, we found the 2-liter bottle needed to be cut above the halfway point—right above where the bottle starts to taper, to make it easy for the top portion to fit into the bottom portion. We also added a bit of food coloring to the water, so sighted students could more easily differentiate water and air. We pre-inserted a crumpled paper towel into the cup portion of the bottle, and secured it with the bottle cap. This lets students see the full apparatus, ready to go, to make it easier for them to replicate on their own.

Another wrinkle we added was the suggestion to repeat the demonstration, but this time with the cap loosened, so that air could be displaced from the cup.

We noted that using cold water rather than room temperature water makes it easier to tell whether the paper towel has gotten wet or not when feeling it with the fingertips.

FLIP PORTION OF DUNK AND FLIP REVISED:

We decided to replace the activity using the meter stick and the sheet of newspaper entirely. Even when done carefully, it can be difficult to smooth the sheet of newspaper perfectly flat so that air doesn't get underneath it from the sides. If the newspaper wasn't flat, the demonstration wasn't as effective. On the other hand, when the demonstration is done well, the force on the paper is so strong that smacking the meter stick causes it to cut through the paper or even snap in half itself.

We tried two replacement activities: in one, we take a long tube of plastic, similar to the tubular plastic bags used to protect newspapers when they're delivered, but much longer. These tubes are sold as Wind Bags by science supply companies. They have a volume of 45 liters. Students try to blow them up like balloons and make little progress even after quite a few lungs full of air. But if they lay the tubes flat and blow toward them from a foot away, the bags quickly fill with air—the stream of air they blow into the bag entrains much more air from the room and carries it into the bag. The demonstration is attention-getting and helps children visualize the fluid dynamics of a room full of air, as opposed to a room full of nothing. On the other hand, it's not ideal for demonstrating the stated goal of showing that air has mass.

The other replacement activity is simply to weigh some air, using a standard 1-liter or 2-liter soda bottle fitted with a special cap that has a bicycle tire-style air valve. These caps can be made with inexpensive or free parts, using valves from discarded bicycle tires, or purchased for under $10US. Children weigh the bottle on a digital scale (under $10US) and write down the result. Then they take the bottle off the scale, attach it to a bicycle pump and add more air into it (ideally, to a pressure of about 50 psi). Then they weigh the bottle with the extra air and find that it's significantly heavier—concrete evidence that air has mass and weight.

DISCUSSION:

Our researchers found that the revisions improved access and engagement:

The changes that were made in the dunk activity were very successful in increasing cognitive engagement of students with both learning and multiple disabilities.

The two alternatives for the flip activity were also well received. Students found the balloon activity amusing. Students were also engaged in the "air in the bottle" activity, although access barriers remained for students with physical disabilities.

– EDC CCT "Kinetic City Empower Research Report" (See Appendix)

Taken together, these activities were very useful at allowing children to investigate properties of air without the need for detailed instruction. The soda bottle apparatus in the "Dunk" portion of the activity clearly shows the air chamber in the upper part of the apparatus, and the flat surface of water underneath and not moving up into the upper portion.

The wind bags that are impossible to blow up like balloons, yet easy to fill if a child blows into them from a distance, may not lead directly to an understanding of entrainment and fluid dynamics, but the mystery does prompt children to consider evidence and advance their own hypotheses to explain what's happening—even with little or no encouragement from the facilitator.

Weighing the soda bottle fitted with the tire valve, adding more air with a bicycle pump, and then discovering that the added air increased the weight considerably and reliably, led children to conclude that air has weight.

However, there were some accessibility issues: the standard bicycle pump used for the activity posed a challenge for children who use wheelchairs or with strength/coordination deficits. It might be possible to offer additional tools to add air pressure, including a hand pump and/or a canister of compressed air.

The small digital scale used to weigh the bottle is difficult to read at an oblique angle or from a few feet away (or at all, if the student is blind.) Therefore, we recommend that the activity should be done with a talking digital scale, which can be purchased for about $25US from The National Federation for the Blind Independence Market online. Not only does the talking scale provide audio feedback for blind or low vision learners, but it makes the data available instantly to all hearing learners within earshot, and solves the problem of our original scale being difficult to read by children who use wheelchairs. Another solution would be to use a digital scale that feeds into a computer, which allows display of the results on a computer monitor, smartboard, or projected image. Once in the computer, results can easily be read out via text-to-speech generation, so blind children can hear them. However, these scales cost $100US or more—not a huge sum as scientific equipment goes, but expensive for inclusion in most after school kits.

Finally, filling up the "Dunk" apparatus with water to just the right level can be challenging for all students, but especially so for low vision or blind students. A one-liter or one-quart vessel will provide the correct amount of water for a two-liter apparatus; students can fill the smaller vessel and empty into the bottom portion of the apparatus. In addition, a low-cost EZ Fill Liquid Level Indicator sounds a loud alarm when a fluid is one inch below the top of a vessel. This is too high a level for the Dunk apparatus itself, but the EZ fill can be used with the correct-sized graduated cylinder or beaker to allow students to get the right amount of water to add to the apparatus.

RESPIRATION STATIONS

Respiration Stations, also known as *Respiration Relay*, is a *Kinetic City Move Crew* activity, meaning it's meant to be a physical activity, played in a gym, playground, or large classroom space. *Move Crews* are generally based on dances, races or physical games like tag.

In *Respiration Stations*, children model the cardio-respiratory system, with different children playing the roles of the lungs, heart, leg muscle, and one or more red blood cells, whose job it is to ferry oxygen molecules through the body. If there's just one red blood cell at a time, the game is *Respiration Stations*; if there's a team of red blood cells who take turns and play against the clock, the game is called *Respiration Relay*. Students learn how the different parts of the body work together to do an important job: deliver vital oxygen to a muscle and take away the waste gas, carbon dioxide.

Students playing the roles of the lungs and heart stand a few feet from each other, while the student playing the leg muscle stands far away (distance depending on play space and on students ability to traverse distances). The student playing the role of “lungs” has a basket full of red balls marked “O_2” for oxygen molecules, and the student playing the leg muscle has a basket of blue balls marked CO_2, for carbon dioxide molecules. Each player wears a placard indicating her/his role with words and a colorful graphic: Lungs, Heart, Muscle, Red Blood Cell.

To begin play, a child playing the role of the red blood cell goes to the lung, the lung takes a deep breath and hands the red blood cell a red oxygen molecule. The red blood cell then goes to the student playing the heart, who makes a “thump-thump” sound and pushes (“pumps”) the red blood cell gently towards the leg muscle. Upon arrival, the red blood cell gives the leg muscle the oxygen molecule, the leg muscle jumps energetically and discards the oxygen molecule into the basket and gives the blood cell a blue CO_2 molecule—the waste product from burning the fuel needed to jump.

The red blood takes the CO_2 and runs back to heart, who again goes “thump-thump” and pushes the red blood cell to the lungs. The lungs take the CO_2, let a out a deep breath and discard the CO_2; then they inhale again, pulling out another oxygen molecule. The red blood cell can then take the new oxygen molecule and repeat the earlier steps or, if the game is being played as a relay, a new red blood cell will accept the new oxygen molecule and run the course. The goal is to get all the oxygen molecules to the leg muscle, and all the carbon dioxide molecules out.

At the conclusion of the game, the players are usually winded from the exertion, providing a good opportunity to discuss the theme of the game. Students are asked to feel their hearts; are they beating faster than usual? Are they breathing harder than usual? What might explain that? Is there any reason to think their muscles might have recently been working hard? What carries oxygen to hard-working muscles? Direct observation of these phenomena lead players to discuss the key points that they modeled during the game.

SUGGESTED REVISIONS:

Our testing of the original activity with our students and teachers went better than expected. Children with mobility and/or vision issues had help from another child or adult facilitator while playing the role of red blood cell, but still were engaged and excited. The field of play could be easily expanded or contracted to accommodate different players. The most common difficulty was reminding players of their roles, especially when they first started. Red blood cells sometimes insistently handed their oxygen or carbon dioxide molecules to the heart, rather than holding on to them to give to the muscle and lungs, respectively.

The original choice of a leg muscle that jumped when receiving the oxygen molecule was, of course, problematic for players who use wheelchairs or who otherwise had difficulty jumping. During testing, we ad libbed new muscle activities, like arm waving or wiggling, and these seemed to work well.

Many of the suggestions from our advisors actually related to making the activity more complex and closer to the actual cardio-respiratory system. For example, they suggested adding chambers to our model heart, and having four children model it together. They also suggested replacing the red and blue foam balls with actual models of the two molecules. Not only would this be more accurate, but blind children would be able to feel the difference between the two.

The advisors also suggested adding sound for each of the three stations (lungs, heart and leg muscle), to make it easier for blind children to navigate. Overall, their suggestions were to:

- Add audio to each station (lungs, heart and muscle);
- Make heart consist of four chambers, adding to the route that the red blood cells run;
- Differentiate between O_2 and CO_2 molecules using differences other than just color;
- Instead of having the muscle be a leg muscle, which jumps when it receives the oxygen, make it more general, so anyone can play, even if they can't jump.

RESPIRATION STATIONS REVISED:

Regarding adding complexity/fidelity to the activity, we couldn't envision a way to model all four chambers of the heart and still have the activity adaptable enough to fit in a smaller classroom space. But at one of our sites, where students were high functioning from a cognitive perspective, we did pair two children to represent the heart's two ventricles, so that one child pushed the red blood cell toward the leg muscle, and the other pushed the red blood cell back to the lungs.

We got slightly larger blue balls with a different texture to represent the CO_2 molecules, so that children could feel the different between them and the O_2 molecules.

Standard audio beacons for use with blind children were too loud and non-specific (making beeps rather than the heart/lung sounds we wanted) for this game. We tested various wearable audio devices that played ten-second samples of recorded sounds and recorded the sound of breathing (for the lungs), thumping (for the heart) and a bouncing sound to represent jumping for the leg muscles. The audio produced by these devices was too distorted and quiet for game use. In addition, the devices had to be re-triggered every ten seconds, which would be annoying in actual game play. Therefore, we had the kids who were playing the roles make their own sounds.

We made the leg muscle into just a generic muscle that made a “boing” sound, like a cartoon spring, and moved energetically in whatever way it wanted.

DISCUSSION:

This physical activity fared differently with learning disability kids and multiple disability kids:

CHILDREN WITH LEARNING DISABILITIES:

Most of the changes that were made in the activity (using different size balls to represent the oxygen and carbon dioxide molecules, using two students to represent different ventricles of the heart, and having students who act as organs make sounds) worked well for the higher functioning students with learning disabilities. While the change in the size of the balls representing the oxygen and carbon dioxide molecules did not appear to change or improve their involvement with the activity compared to the original activity, it did not distract from it. Having two students serve as different parts of the heart appeared to increase their cognitive engagement with the activity, and to help them make connections to the circulatory system. Having students make sounds for the organs did not work as well, as students seemed to struggle with keeping a rhythm and were a little embarrassed by having to do this.

CHILDREN WITH MULTIPLE DISABILITIES:

Students with multiple disabilities demonstrated a high level of engagement with the adapted version of the activity. With sufficient space and some of the their teachers’ assistance, they were able to physically engage in it. Their level of cognitive engagement was high as well, and due to a teacher’s facilitation (she assigned students to serve as the different organs), students participated more in this version of the game than in the original version in which teachers served as the organs. However, students needed frequent reminders and directions about what they had to do (which organ the red blood cell had to move to next, what each organ had to do), and even their teachers where confused at times. It was not clear how much students knew about the circulatory system and whether *and how they connected the activities to whatever level of knowledge they had. The change in the size of the balls representing the oxygen and carbon dioxide molecules did not appear to change or improve their engagement in the activity. (See Appendix)*

During testing, we spontaneously began performing the activity to a rap beat and that seemed to have a focusing effect—especially when we had the lungs, heart and leg muscle produce their sounds in beat with the music. This suggests a possible future change to the activity: record a song that could be included as a sound file included with the activity. A side benefit of this enhancement would be that it can be recorded with sounds representing the lungs and heart in one audio channel and the sounds representing the leg muscle in the other channel. By using two speakers, teachers could set up the activity so that blind students could participate by following the direction of the two primary sounds. The advent of powerful, low-cost Bluetooth speakers would allow educators to set up the system wirelessly, indoors or out.

Other ideas that came from our second round of testing, which had been overlooked in our initial round of testing, were to add guideposts—physical indicators for blind players and/or color-coded arrows for sighted players—to indicate the path for oxygenated red blood cells going out to muscles and deoxygenated blood cells returning, and make the identification placards worn by each player dimensional and enhanced with braille, so that blind students can feel the difference.

OVERALL OBSERVATIONS

Our intent in working on five afterschool learning activities, representing five general types of activities (computer games, hands-on demonstrations, physical games, art activities and writing activities) was to see how effective we could be at enhancing accessibility with a reasonable level of effort.

We started out with a high level of skepticism, especially regarding highly visual activities, like the *All Systems Are Go* computer game, and those for which effective engagement seemed to rely on mobility and coordination, like *Respiration Relay*. Overall, however, we were pleasantly surprised that we could expand the accessibility of all five games substantially with changes that were not difficult to implement and that enhanced the activity for all children, regardless of ability level.

This stands in contrast to the low percentage of informal learning STEM activities now available that are accessible. Of the thousands of STEM activities that we found online, only a small percentage were listed as usable by blind/low vision children, and most of these activities related specifically to the senses, like discerning objects using touch, or echolocation like a bat, rather than about basic science like geology or chemistry.

A quick review of the activities reveals that many, if not most, could be made significantly more accessible with just a small amount of effort. Furthermore, had accessibility been a concern when the activities were designed, they could have been made accessible for virtually no additional cost.

Some of the most broadly useful enhancements include:

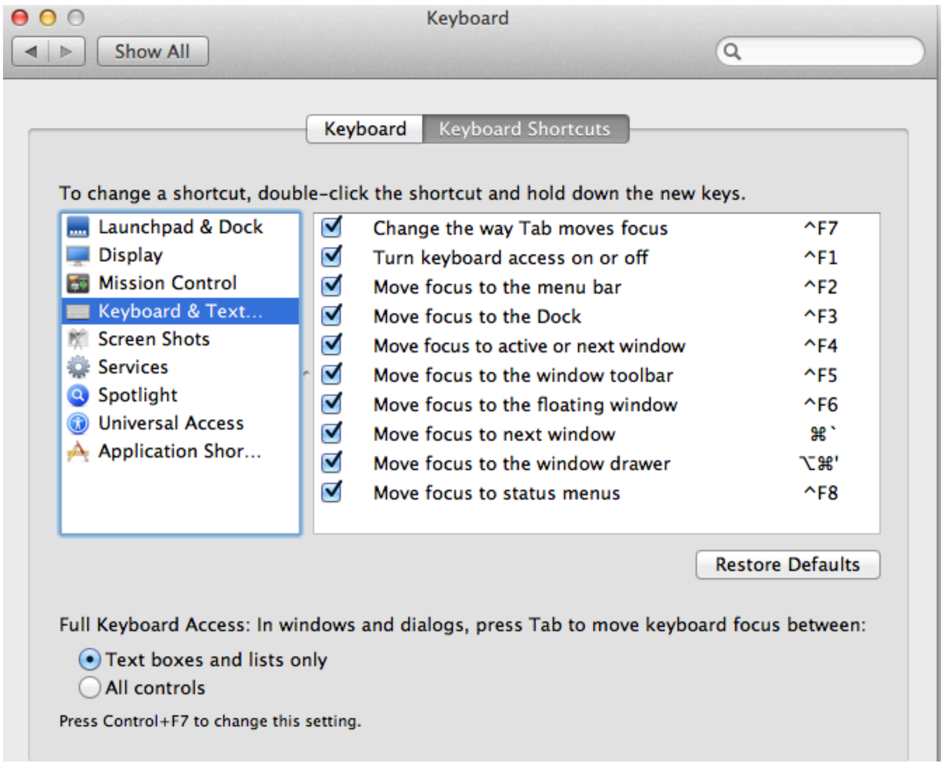
Adding audio narration to accompany screen text for web pages and games

In our case, this was a matter of recording narration for each button, object and text field in the game, and then adding each one into the Flash game program. This allowed us to use our own voices to match our game environment. For pages that are viewed in a browser, there are native voice systems in modern operating systems that users can activate in the computer's control panel or system preference screen under "Universal

Access". In addition, there are now text-to-speech programs for websites that are free for non-commercial use, instantly creating human-sounding speech from screen text when the user selects the "Play" button. The programs are embedded right into the code for the web page, work with most modern browsers, and allow more voices and other features than may be available via the Universal Access features of a computer. These features not only allow blind and low vision students to participate more fully, but help students learn to read by pairing speech to text, assist language learning efforts, and make the game or web page more engaging. For cases where the audio is distracting, e.g.,, if the educator is speaking while students are accessing the page or game, the audio can be toggled off, or the audio volume can be reduced.

Adding "Full Keyboard Control" to games and instructional web pages

For our Flash game, this required about 20 hours of computer programming, but would take less time if it had been specified when the game was originally designed. Many web-based informal education games are quite simple, consisting of textual information screens with decorative graphics, followed by multiple-choice quizzes. For these, allowing players to use the tab button to move through selections and the space bar to trigger a selection is easily implemented and useful for many participants, including children who may have difficulty positioning the mouse over the tiny multiple-choice bubbles. Other computer games might require more ingenuity, but most of them could be made better and more accessible with minor changes. For regular web pages, the ability to use the tab button to move through targets on a web page, and use the space bar to select or trigger targets—like Start and Back buttons—is already included in modern operating systems. In a computer's control panel or preference window, users need only select Full Keyboard Access to activate these features*.* The games or webpages themselves should be designed to take full advantage of this feature, so that users tab through items in a logical manner.



Making flat graphics tactile

There are many ways to make line art and other graphical material tactile, including simply outlining the art with waxy Wikki Stix strips, using pens that produce raised lines, using printers that produce raised-line output or contracting with companies that create artwork specifically for this purpose. Artwork can also be drawn or printed on heavy paper or card stock and then cut out, so students can feel the shapes. As with the other suggested changes, providing tactile as well as visual input may enhance the resource for sighted students as well as those who are blind or have low vision.

Providing multiple modes of expression

Just as adding a tactile element can enhance educational resources, so, too, can providing multiple opportunities for expression. Our original activities required students to demonstrate their understanding through one specific method, like writing a story or drawing a picture. Encouraging students to share what they've learned in any of a variety of ways is more inclusive and can inspire curiosity. Instead of drawing a creature, why not mold it out of modeling clay, make it out of pipe cleaners, or assemble it from a box of animal parts? Or even act it out, describing how your creature lives in its environment?

Including active educator participation

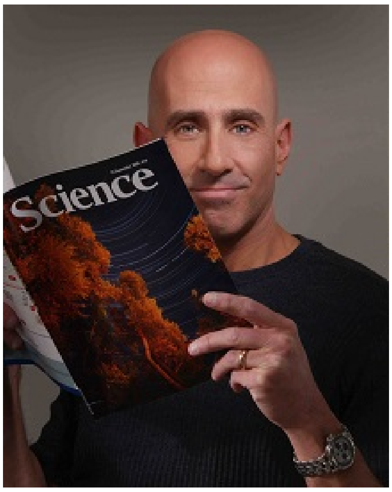
New technologies and design enhancements do not reduce the need for active, engaged instructors to mediate the learning activities, especially for students with more severe disabilities. Teachers, program leaders, and other adults working with students with disabilities need instructions for how to effectively facilitate the activities for students in ways that encourage their independence and that promote physical, cognitive, and social engagement.

Promising New Technologies

Our work is in its early, exploratory phase, and we have not conducted an exhaustive study of new tools to enhance accessibility. However, two promising areas that we have identified are:

Computer interfaces that allow multiple modes of input and output, leading to a Universal Workstation for students. While the addition of keyboard control to our game interface was a big improvement, computer interfaces could be improved significantly for all students, through Universal Design principles, to help them save, interpret and share what they learned. Such workstations would provide all students multiple means of data input (including keyboard, voice and handwriting/drawing), guided methods of data and document organization, and guided means of expression. Students would then be empowered to share their findings and ideas in many ways, including essays, formal papers, audio, video, various modes of presentation, and posters.

A standardized audio and tactile interface and development platform for computer tablets. This would allow creation of tactile, 3D overlays for tablets that interact with mobile apps, with both audio and video triggered by touch. These sheets can allow both blind and sighted students to explore circuit design, topography, charts and graphical material. Manufactured or 3D-printed objects can also interact with the tablets, allowing, for example, creation of creatures suited to an environment, constructed from various parts, like heads, bodies, appendages, etc. The computer tablet could provide feedback, e.g., "How will your creature use those flippers in this environment?" While the technology already exists, it hasn't yet been standardized and optimized. Once mature, this interface would allow UDL implementation in a variety of novel learning resources.



Bob Hirshon is Program Director for Technology and Learning at the American Association for the Advancement of Science (AAAS) and host of the daily radio show and podcast *Science Update*. He is Principal Investigator on the NSF-funded project *KC Empower*, which examines how informal science activities can be made more accessible to children with disabilities. He oversees the *Science NetLinks* project for K-12 science teachers (www.sciencenetlinks.com). Hirshon's Qualcomm Wireless Reach project, *Active Explorer*, allows educators to create mobile phone and tablet explorations for children, called *Quests*. Hirshon also heads up *Kinetic City*, including the Peabody Award-winning children's radio drama, McGraw-Hill book series and Codie Award- winning website and education program. He is a member of the Education and Public Outreach team for NASA's MESSENGER project to planet Mercury, and hosts the annual *AAAS Science Film Showcase* event, featuring the year's best science films and videos and the producers who created them. He can be heard on XM/Sirius Radio's *Kids Place Live* as "Bob the Science Slob," where he discusses science and answers call in questions from kids. Hirshon is a Computerworld/ Smithsonian *Hero for a New Millennium* laureate. Prior to working at AAAS, Hirshon was a producer and correspondent at WGBH-TV for the weekly television show *Science Gazette*.

Laureen Summers is a Project Director at the American Association for the Advancement of Science (AAAS) and has worked on disability-related projects at AAAS since 1992. Since 1996, she has worked on—and now directs—the Entry Point! internship program for undergraduate and graduate college students with disabilities. She has supported interns through multiple summer opportunities, degree completion, and career placement. Entry Point! is the signature program of the AAAS Project on Science, Technology and Disability. Summers studied Liberal Arts at Cazenovia College in New York, at the College on the Potomac, in Washington, DC, and has taken additional coursework in Special Education at the George Washington University. Summers, a woman with cerebral palsy, is passionate about bringing disability into conversations about diversity and issues of self-efficacy. She has contributed to several publications and has worked in the disability field for 30+ years.

Babette Moeller, Ph.D. is a Distinguished Scholar at the Center for Children and Technology of the Education Development Center. Her work focuses on the development of and research on educational programs across the curriculum that help ensure elementary, secondary, and post-secondary students with disabilities are included in and benefit from educational reform efforts. As project director of numerous EDC research and development projects, she contributes her extensive experience designing and implementing technology-supported programs in both general and special education, providing professional development for teachers and administrators in a variety of settings, and conducting formative and summative evaluation research. She is the lead author of the *Math for All* program published by Corwin Press. *Math for All* is a professional development program that assists districts as they aim to implement standards-based math education with a wide range of learners, including those with disabilities, in grades K–5.

Dr. Wendy Martin is a research scientist at **EDC|CCT**. Dr. Martin has worked on many projects that use collaborative co-design to adapt informal STEM programs and materials for formal education settings. She is Principle Investigator on the NSF-funded *Digital Games as Analogical Sources for Science Learning,* which explores how middle-school science teachers can integrate games into instruction to support STEM learning. She was lead evaluator on both the NSF-funded *ScratchEd*, in which educators, researchers, and program developers co-designed assessments of computational thinking, and on the NSF-funded *Work-based Learning*, which uses innovative methods for preparing incumbent workers for advanced technology careers, and was an evaluator for NSF-funded *KC Empower,* which redesigned science activities for students with disabilities. She also was project manager on *Possible Worlds,* funded by the U.S. Department of Education's Institute of Education Science, which used a collaborative co-design process to create digital games and resources to address science misconceptions held by middle-school students.

KC Empower is a project of the American Association for the Advancement of Science (AAAS) Directorate for Education and Human Resources Programs

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Activity photos taken by Bob Hirshon.

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Kinetic City Empower

Research Report

Submitted to:
American Association for the Advancement of Science

Prepared by
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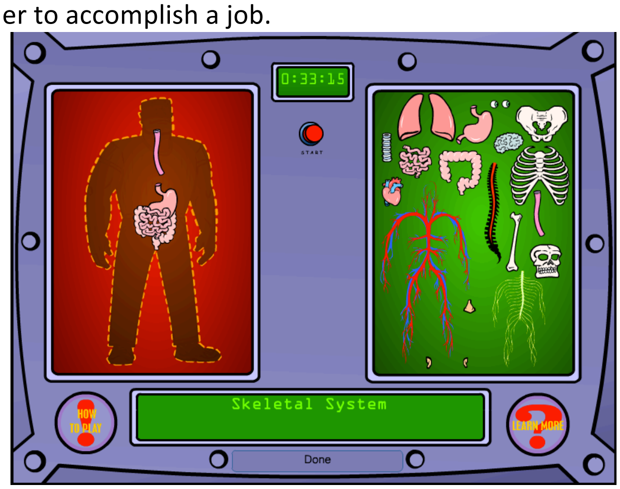
August 2015

Introduction

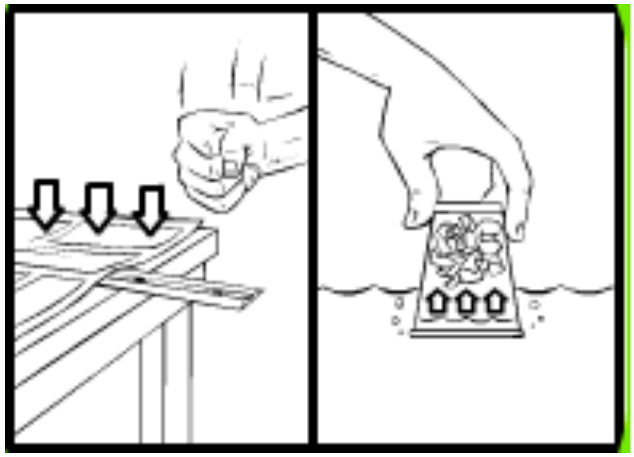
The overall purpose of the Kinetic City (KC) Empower project was to examine how informal science activities can be made accessible for students with disabilities. The premise of this project was that all students, including those with disabilities, are interested in and capable of engaging in science learning experiences, if these experiences are accessible to them. Drawing on resources from Kinetic City, a large collection of science experiments, games, and projects developed by the American Association for the Advancement of Science (AAAS), the project researched and adapted five afterschool science activities guided by universal design for learning principles.

The focus in this project was on five Kinetic City activities that were chosen because they represented different genres of activities: a computer-based activity, a kinesthetic activity, a set of two hands-on activities, a writing activity, and a drawing activity. Specifically, KC Empower investigated the following five activities.

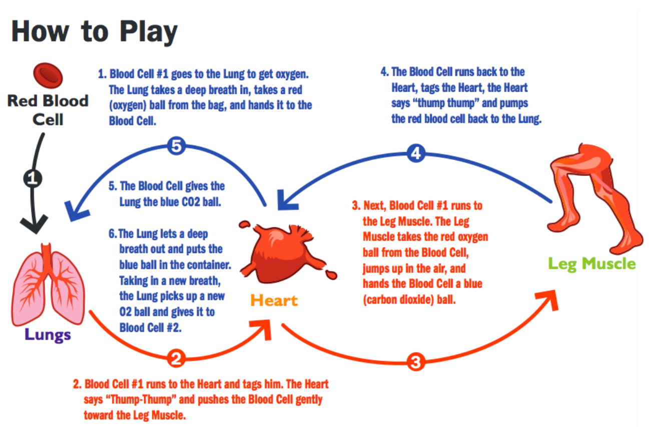
All Systems Are Go is a Flash-based game in which players have to assemble the internal organs for a character, Arnold Rutabega, who has lost all his organs. The original game presents players with a collection of organs, which they have to drag and drop onto the outline of Arnold's body to assemble four major systems of the human body: the circulatory/respiratory, skeletal, digestive, and nervous systems. A Learn More button brings up a text essay on the major systems of the human body, describes the organs and other parts in each system, and explains how they work together to accomplish a job.



Dunk and Flip is a set of two hands-on activities that illustrate that air has mass and takes up space. In the dunk activity a paper towel is pushed into the bottom of a paper cup, and this cup is submerged, face down, in a tub of water. When the cup is removed from the water, students notice that the paper towel stayed dry. This is because air was already in the cup, taking up space and keeping the water out of the cup. In the flip activity, a yardstick is placed on a table sticking out about halfway from the edge. The portion of the yardstick that is on the table is covered with a large sheet of newspaper, spread out flat. Students are asked to push down on the yardstick and observe what happens. They observe that the yardstick is very hard to push up. They are then asked to repeat this activity, crumpling up the newspaper and putting it on the yardstick. Students discover that the newspaper now flies up in the air very easily when they push on the yardstick. This activity demonstrates that air is pushing down on everything. The flat newspaper has a much larger surface area than the crumpled up newspaper and therefore more air mass is pushing on it.



Respiration Stations is a kinesthetic activity that simulates the circulatory/respiratory system. Players assume the roles of the heart, lung, leg muscle, and one or more red blood cells. The red blood cell has to move from the lung to the heart to the leg muscle to deliver an oxygen molecule (represented by a red ball), and pick up a carbon dioxide molecule (represented by a blue ball), to transport it back to the heart and the lung, where it exchanges the carbon dioxide molecule (blue ball) for an oxygen molecule (red ball). The red blood cell then repeats the above steps. Students learn how the different parts of the body work together to do an important job.



Where the Weird Things Are is a writing activity in which students are asked to describe the environments in which creatures with various features might live. Students are shown pictures of six fantasy creatures and are asked to make up a story about them that describes where the creatures live and how their strange features help them survive there.

Blueprint for a Beast is a drawing activity which engages students in thinking about how the features of a creature relate to the environment it lives in. In this activity, students are asked to draw a creature that can live in one of these unusual environments: inside a volcano; 35,000 feet above the ground (where airplanes fly); on an iceberg in the middle of the ocean; under the hood of a car; or in your nose. In designing their creature, students are tasked to think about how it moves, drinks and eats, and protects itself from any dangers its environment presents.

The KC Empower project was carried out in three major phases. In Phase 1, we conducted research with students with disabilities to examine what access barriers students experience as they engage with the original five Kinetic City activities. In Phase 2, the activities were revised based on information gathered through the initial research and input from a national advisory board. Table 1 (pages 5 and 6, below) summarizes the revisions that were made in the activities. In Phase 3, we tested the adapted activities to examine if the changes were successful in improving the accessibility of the activities for students with a range of different disabilities. The focus in this project was on students in grades 3–12 with physical, sensory, cognitive, and developmental disabilities. This report summarizes the research that was conducted as part of this project.

Methods

The purpose of the research was to obtain information about the accessibility of the five Kinetic City activities under investigation to guide their continual improvement. The research was designed to collect information about the access barriers that the original activities posed to students with a variety of disabilities, and to assess how the adaptions that were made to the activities affected their accessibility for these students. Our observations were guided by the framework for inclusion in informal science education (Reich, Rich, Rubin, & Steiner, 2010), and focused on the following questions.

1. Physical Interaction with the Activity

- Are the activities designed in such a way that individuals with diverse abilities can interact with them?
- Is the information in the activity conveyed in a variety of formats so that individuals with diverse abilities can perceive it?
- Can individuals with diverse abilities manipulate or cause things to happen within the activity?

2. Cognitive Engagement with the Activity

- Is the information conveyed using a range of media to allow individuals with diverse abilities to engage with the materials?
- Do the materials take into account individuals with a range of learning and cognitive skills?
- Do the materials take into account individuals with ranges of experiences and varying sets of background knowledge?

3. Social Interaction

- Are the activities set up to comfortably and safely foster and facilitate encounters and engagement among individuals with diverse abilities?
- Are the activities designed to provide meaningful reasons to foster and facilitate interactions and discussions among individuals with diverse abilities?

Participants

The participants in the research were students with a range of disabilities, and their teachers, from two schools in Washington, DC. The first group consisted of 14 students with learning disabilities (including dyslexia, attention deficit disorder, attention deficit hyperactivity disorder, and anxiety) from a small private school. These students ranged in age from 8 to 12 years and were predominantly male. The second group consisted of about 35 students with multiple disabilities (i.e., cognitive, physical, speech, visual, learning, and developmental disabilities and other health impairments) who attended a special education public school. The students in this group ranged in age from 10 to 22 years and about half of them were male and half were female. Few of the students were able to read or write, and several were nonverbal. Most students received one-on-one support from a teacher or aide.

Table 1: Revisions in the Five Kinetic City Activities

All Systems Are Go

- Made the game keyboard accessible, in addition to mouse accessible.
    - Making all possible selections into buttons that can be accessed by the tab button and selected with the spacebar or enter key.
    - Shift Tab should tab through selections backwards.
    - Game should start with cursor at top; spacebar should trigger "Start Game."
    - Add a visual indication of keyboard focus.
    - Keyboard commands should function on all screens, including the Play Screen, the How To Play screen, and the Learn More screen.
    - For gameplay, put keyboard focus on any body part, beginning with top one; then use left, right, up, and down arrow keys. Keyboard focus should highlight part and play audio.
    - When highlighted, enter key or space bar selects.

- Added audio for all buttons and selections; added narration for How to Play and Learn More.

- Gave the organs in the game "object permanence"—for example, when an organ was dragged from one screen to another, there was never a reoccurrence of that organ in the screen from which it was dragged.

Respiration Stations

- The balls representing carbon dioxide and oxygen molecules were replaced, so that the balls representing the carbon dioxide molecules were slightly larger and had a different texture than did the balls representing the oxygen molecules.

- Students who played the roles of the heart, lung, and leg muscle were asked to make sounds to represent their organ.

- In a variation of the game, two students were asked to represent the heart's two ventricles, so that one child pushed the red blood cell toward the leg muscle, and the other pushed the red blood cell back to the lungs.

Dunk and Flip

1. Dunk Activity

- The plastic tub and paper cup were replaced with a 2-liter soda bottle, cut in half to make a water tub (the bottom half of the bottle) and a cup (the upper half of the bottle). Food coloring was added to the water, so students could more easily differentiate water and air.

2. Flip Activity

AAAS developed two replacement activities.

- Students were given a long plastic tube with a volume of 45 liters and asked to blow it up like a balloon. They noticed that they made little progress even after several blows of air. They were then asked to lay the tube flat and blow toward it from a foot away. They notice that it quickly fills with air—the stream of air they blow into the tube entrains much more air from the room and carries it into the tube. The demonstration helps students visualize the fluid dynamics of a room full of air, as opposed to a room full of nothing.

- Students are asked to weigh air, using a standard 1-liter or 2-liter soda bottle fitted with a special cap that has a bicycle tire-style air valve. Students weigh the bottle on a scale and write down the result. Then they take the bottle off the scale, attach it to a bicycle pump, and add more air into it (ideally, to a pressure of about 50 psi). Then they weigh the bottle with the extra air and notice that it is significantly heavier.

Where the Weird Things Are

- The original activity had just black-and-white line art to show the creatures. For the revised activity, AAAS contracted with a company called Touch Graphics to recreate the artwork as a book of 3D raised images, with colors and textures.

- In addition, each creature was divided into parts, like "head," "body," and "tail," and each of these parts had a text description, i.e., "This creature has a long tail with a spike at the end." The descriptions are given in both letters and braille. Talking pens were programmed to read the descriptions out loud when a user holds the pen over a creature or a particular feature.

- When presenting the activity to students, they had access to an assortment of plastic animals, such as porcupines and walruses, and the facilitator engaged students in a discussion of how these real animals' features helps them survive in their environments.

- The title of the activity was changed to "Your Creature's Features."

Blueprint for a Beast

- In addition to being provided with a variety of art supplies and papers, students also had access to modeling clay and wiki sticks to enable them to create their creatures in 3D.

- The facilitator introduced the activity by reading *The Mixed-Up Chameleon* by Eric Carle, stopping to ask students about different characteristics described in the book and what each animal did with its adaptation.

- Students were asked to show and describe their creatures for the group.

- Students were given the option of taking their creatures home with them.

Procedure

The procedures for assessing the accessibility of the original activities and the adapted activities were the same. The students participated in groups with their teachers, either during afterschool hours or during learning center time. A facilitator from AAAS first introduced and demonstrated each activity, and then students had the opportunity to engage in the activity themselves in small groups or individually, with the help of their teacher or aide where needed. Given the size of the groups in the two schools, the activities were carried out in sequence with the students with learning disabilities. For students with multiple disabilities, workstations were set up for each of the five activities—similar to a science fair—and students circulated through these workstations individually or in small groups. Researchers observed students and teachers as they engaged in the activities, and conducted informal interviews with students and teachers whenever feasible. Observations and interviews were recorded through ethnographic notes. The researchers also collected samples of students' work.

Analysis

Ethnographic field notes and work samples were analyzed thematically, using the framework for inclusion in informal science education (Reich, Rich, Rubin, & Steiner, 2010) as a guide.

Findings

Overall, we found that virtually all students were able to participate in the activities, either independently or with the help of their teachers, and most, if not all, of the students appeared to be engaged with the activities. Below, we report findings for each of the five activities under investigation in turn.

1. All Systems Go

Students' and Teachers' Responses to the Original Activity

Physical Interaction with the Activity

• The drag-and-drop feature can be challenging, especially for students with fine motor coordination issues.
• The use of the Smart Board (using a tennis ball on a stick as the input device) made it easier for some students with physical disabilities to interact with the game.
• Teachers suggested providing a hands-on option of the game (in 3-D or 2-D).

Cognitive Engagement with the Activity

• Students gravitated to this activity and were very engaged.
• Students did not pay much attention to the clock.
• Some of the game mechanics were confusing for students (e.g., when they made a mistake, all the organs previously assembled went back to the right side of the screen while simultaneously being displayed on the left; when they finished one system, the body parts already assembled on the left side of the screen reappeared on the right).
• Students found it visually confusing that body systems were superimposed onto each other.
• Some of the students with learning disabilities did not like the sound of Arnold's voice.

• Some students with learning disabilities questioned the logic of Arnold talking while "being in surgery."
• Some students with learning disabilities wanted to see all the bones.
• Very few students explored background text.
• Teachers offered several suggestions for improving students' cognitive engagement with the activity:
    - Add labels and have computers read them.
    - Simplify what's on the screen (use separate screens for different systems).
    - Don't have organs reappear on the right side of the screen when students make a mistake.
    - Give feedback when students get it right.
    - Reinforce systems with songs (e.g., drumbeat to go with the heart).
    - Eliminate the time element.

Social Interaction

• The use of the Smart Board facilitated student collaboration.

Students' Responses to the Adapted Activity

Physical Interaction with the Activity

• Students with learning disabilities were able to interact with the adapted game more smoothly, without the frustration that the drag-and-drop feature had created.
• Students with learning disabilities liked the audio descriptions/labels for the organs. One student with a learning disability explored the audio labels for the organs.
• Students with learning disabilities suggested using voice control to select an organ (selecting it by saying its name).
• Students with learning disabilities suggested using the arrow keys (rather than the tab key and space bar) to move the organs.
• Some students with learning disabilities found the narrator's voice "annoying."
• One student with a learning disability indicated that he could not hear the audio narration very well.
• A student with fine motor issues used drag-and-drop to interact with the activity and struggled with it. He did not try interacting with the game using the tab key/space bar. His teachers suggested that a mouse would help him interact better with the game.

Cognitive Engagement with the Activity

• Students with learning disabilities did not get frustrated when they made a mistake in the adapted version, because the organs that they had already successfully placed did not disappear.
• Students with learning disabilities liked that the organs that they placed got removed from the screen on the right.
• One student with a learning disability played the game against time and was able to finish it in less than 2 minutes.
• Students with learning disabilities did not pay attention when the audio narration was played.
• One student with a learning disability used trial and error to place organs for the circulatory/respiratory systems, and the nervous system (toward the end of the game).

Social Interaction

• Playing the game on the Smart Board or with an overhead projector facilitated student collaboration.

Summary

The key changes that were made in the game (offering an alternative to the drag and drop feature for moving the organs, providing audio labels for the organs, changing the response that students got when they make a mistake, removing from the right side of the screen organs that have been placed) were successful for improving the physical accessibility of the game and students' cognitive engagement with it.

Further changes could be made to improve the quality of the audio narration and to provide alternative ways to convey the information it transmits. Currently, the activity is designed for a single player. Alternate versions could be developed to support social interaction among multiple players. Our observations that some students did not make use of the improved features also raise the question of how students and teachers will be made aware of the different options for interacting with the game, so they can make choices about what works best for them.

2. Dunk and Flip

Students' and Teachers' Responses to the Original Activities

Physical Interaction with the Activities

• Students with multiple disabilities did not engage in the activities hands-on.
• Students with learning disabilities were at first a little tentative to do the activities hands-on; they got more involved with the dunk experiment than with the flip experiment.
• Students with learning disabilities had some difficulty with replicating the dunk experiment exactly (some air escaped when they immersed the cups, so their paper towels got wet), which made them wonder why this happened.
• A teacher of students with multiple disabilities suggested giving students permission to manipulate things hands-on.

Cognitive Engagement with the Activities

• Few of the students with multiple disabilities were drawn to these activities on their own, but some of them got engaged when the facilitator demonstrated the activities.
• Students with learning disabilities, while intellectually engaged and curious, were at first a little tentative to do the activities hands-on. The students stayed in their seats to watch. They were somewhat more engaged in the dunk activity than in the flip activity.
• At least some of the students with learning disabilities had an understanding of the concepts of air taking up space.
• Students with learning disabilities were able to make predictions about what would happen to the paper towel when the cup was immersed in the water.
• Teachers of students with multiple disabilities offered several suggestions for improving students' cognitive engagement with the activities:

- Find a way to make air visible (e.g., use smoke).
- Give students an opportunity to feel the air as it escapes.

- Help students see the connection between the dunk and flip activities.
- Help students see the connection between the activities and their real life.

Social Interaction

• Demonstration of the activity by an adult increased students' engagement with it.
• Teachers of students with multiple disabilities suggested that it would be important for a teacher to demonstrate and facilitate the activities.

Students' Responses to the Adapted Activities

Physical Interaction with the Activities

• Students with learning disabilities were more likely to interact with the adapted versions of the activities in a hands-on manner (they wanted to feel the paper towel and the plastic tube).
• Students with learning disabilities liked the adapted version of the dunk activity more because they could see better what was going on.
• Students with multiple disabilities did not interact with the dunk activity hands-on.
• Three students with multiple disabilities were able to use the air pump and scale to measure and record the weight of air in the 2-liter bottle.
• One student with multiple disabilities, including fine motor control issues, had difficulty with putting the bottle with air on the scale. He also had difficulty reading the scale from a sitting position (the student used a wheelchair). The teacher assisted with reading the weight on the scale. The student also had difficulty with pushing down the pump to put more air into the bottle. The facilitator helped with the pumping.

Cognitive Engagement with the Activities

• Students with learning disabilities were more engaged in the adapted version of the dunk activity. Some students got out of their seats and moved closer to the demonstration to better observe what was happening. Students passed around the top to feel the paper towel.
• One student with multiple disabilities was able to offer air as an explanation for why the paper towel did not take on the green color.
• Students with learning disabilities found the plastic tube demonstration amusing. They got out of their seats and wanted to feel the plastic tube

Social Interaction

• Demonstration of the activity by an adult increased students' engagement with it.

Summary

The changes that were made in the dunk activity were very successful in increasing cognitive engagement of students with both learning and multiple disabilities. Using the soda bottle helped students to see more clearly what was happening with the paper towel, and they were better able to connect the activity to the presence of air. The success of this activity appears to rely on the demonstration by a teacher. Even with the adapted version, students were somewhat hesitant to engage in the activity in a hands-on manner. The two alternatives for the flip activity also were well received. Students found the plastic tube activity amusing. Students were also engaged in the "air in the bottle" activity, although access barriers remained for students with physical disabilities.

Given the importance of an adult to facilitate the two activities, further improvements could be made to provide guidelines for teachers as to how to demonstrate the activities, how to scaffold students' thinking by asking questions, how to encourage students to follow along in the activities in a hands-on manner, how to support student-to-student interaction and collaboration within the activities, and how to assist students in carrying out the activities while at the same time supporting their independence.

3. Respiration Stations

Students' and Teachers' Responses to the Original Activity

Physical Interaction with the Activity

- All students with multiple disabilities participated, including students with walkers and wheelchairs.
- For students with multiple disabilities, adults served as heart, lung, and muscle, and students as red blood cells.
- Many of the students with learning disabilities volunteered to serve as heart, lung, and muscles. Other students took turns serving as red blood cells.
- One teacher of students with multiple disabilities pointed out that sufficient room is required to carry out this activity.

Cognitive Engagement with the Activity

- Students with multiple disabilities were very excited about this activity. Many students wanted multiple turns.
- Most of the students with learning disabilities were excited about this activity as well. There were two students who appeared a bit hesitant to participate.
- At least some of the students with learning disabilities demonstrated an understanding of the circulatory system. Some students knew that the heart has four chambers.
- Teachers of students with multiple disabilities and with learning disabilities facilitated the activity by giving verbal directions or guiding students as to what to do next (e.g., muscle to jump when exchanging balls, directing red blood cells where to go).
- Several teachers of students with multiple disabilities wondered what students got out of the activity. They felt that the activity is useful to prepare students for learning about the circulatory system or to reinforce previous learning about it.

Social Interaction

- The activity requires coordination among multiple players.

Students' and Teachers' Responses to the Adapted Activity

Physical Interaction with the Activity

- Students with learning disabilities were able to do the activity and follow the steps without prompting.
- Students with learning disabilities suggested including other body parts (not just the leg muscle) in the activity.
- Students with learning disabilities suggested using models of actual oxygen and carbon dioxide molecules, rather than representing them with balls.
- Students with learning disabilities reported that they found it hard to keep a beat when making the organ sounds; they suggested having some background rhythm to help keep them on track.

• Teachers of students with multiple disabilities helped to walk the student who was acting as the red blood cell from one body part to another, and told him what he had to do.
• The students who acted as heart and muscle needed reminders about what to do.
• At some point, the teachers of students with multiple disabilities were somewhat confused about the instructions for the activity.

Cognitive Engagement with the Activity

• Students with learning disabilities were engaged and appeared to enjoy the activity.
• Some students with learning disabilities appeared embarrassed to make the sounds of the organs out loud.
• Students with multiple disabilities participated in all aspects of the activity, with assistance from their teachers.

Social Interaction

• The activity requires coordination among multiple players.
• Teachers of students with multiple disabilities facilitated the activity in multiple ways. They assigned roles to students (e.g., heart, muscle, leg), guided them from one body part to the next, and reminded the body parts what they had to do.

Summary

Most of the changes that were made in the activity (using different-sized balls to represent the oxygen and carbon dioxide molecules, using two students to represent different chambers of the heart, and having students who acted as organs make sounds) worked well for the higher functioning students with learning disabilities. While the change in the size of the balls representing the oxygen and carbon dioxide molecules did not appear to change or improve their involvement with the activity compared to the original activity, it did not distract from it. Having two students serve as different parts of the heart appeared to increase their cognitive engagement with the activity, and to help them make connections to the circulatory system. Having students make sounds for the organs did not work as well, as students seemed to struggle with keeping a rhythm and were a little embarrassed by having to do this.

Students with multiple disabilities demonstrated a high level of engagement with the adapted version of the activity. With sufficient space and some of the their teachers' assistance, they were able to physically engage in it. Their level of cognitive engagement was high as well, and due to a teacher's facilitation (she assigned students to serve as the different organs), students participated more in this version of the game than in the original version in which teachers served as the organs. However, students needed frequent reminders and directions about what they had to do (which organ the red blood cell had to move to next, what each organ had to do), and even their teachers where confused at times. It was not clear how much students knew about the circulatory system and whether and how they connected the activities to whatever level of knowledge they had. The change in the size of the balls representing the oxygen and carbon dioxide molecules did not appear to change or improve their engagement in the activity.

Further improvements could focus on providing guidelines for teachers about how to facilitate this activity, especially for students with more severe disabilities. These guidelines could include suggestions for how to help students connect the activity to the circulatory system and how to assist students in carrying out the activities while at the same time supporting their independence.

4. Where the Weird Things Are/Your Creature's Features

Students' and Teachers' Responses to the Original Activity

Physical Interaction with the Activity

• Most students with multiple disabilities who participated in this activity dictated their responses to the teachers.

• Students with learning disabilities struggled with writing their ideas down on paper. They had lots of good ideas about their creature, the environment it lived in, and how its features helped it, but their writing was illegible.

• Teachers of students with multiple disabilities offered several suggestions for improving the accessibility of the activity:

- Eliminate the writing component.
- Give students environments (pictures) to choose from (or give them elements of environments that they can compose).
- Use big pictures, and ask students what part of the picture does the creature live in.
- Give students more specific writing prompts (e.g., ask them to explain how the features are well-adapted to certain environments).

Cognitive Engagement with the Activity

• A small number of students with multiple disabilities (about 5–6) gravitated to this activity.

• Students with learning disabilities were not very interested in this activity (only about half of the group participated).

• When the facilitator showed the pictures of the creatures, some students with multiple disabilities did not look at them. But some students answered some of the facilitator's questions about where the creature lives ("up high," "in the ground"); other questions that the facilitator asked (e.g., "How tall is the creature?") remained unanswered by the students. The teachers jumped in and provided some answers.

• The teachers helped students with multiple disabilities by asking them questions.

• The teachers suggested to some of the other students with multiple disabilities that they color in the pictures of the creatures.

• Teachers of students with multiple disabilities offered several suggestions for improving students' cognitive engagement:

- Keep it simple—focus on one body part and its interaction with the environment.
- Use real animals—picturing something that is not real can be challenging.
- Use simpler creatures (e.g., creatures that can't get wet).
- Give students an example of a creature matched with its environment.
- Give students story starters (words or pictures).
- Make the worksheet bigger and more colorful.

Social Interaction

• The activity did not afford much interaction among students.

Students' and Teachers' Responses to the Adapted Activity

Physical Interaction with the Activity

• The students with learning disabilities said that they liked the "Creature's Features" book. They said that they got a better sense of the creatures because they were in color and had some descriptions. The students also liked that they could access the descriptions through audio or by reading.
• Students with learning disabilities, as well as students with multiple disabilities and their teachers, had some trouble getting the "Creature's Features" book to work (using the pen to hear the audio description). They were assuming that they had to tap the pen when they had to slide it.
• Teachers of students with multiple disabilities suggested attaching the "Creature's Features" book to speakers so that the volume of the audio can be increased. They also suggested increasing the font size of the text.
• A teacher of students with multiple disabilities suggested that students would be better able to participate in this activity if they could share their ideas with a GoTalk machine (https://www.spectronics.com.au/product/gotalk-4) and pictures. It would be helpful to give students a choice of three environments and then have them pick which one would best match the creature. The teachers indicated that students with multiple disabilities benefit from more structure rather than having a very open-ended activity. These students also need to have some vocabulary options.

Cognitive Engagement with the Activity

• Among the students with learning disabilities, only the girls showed an interest in the "Creature's Features" book.
• Students with learning disabilities suggested that the "Creature's Features" book could be enhanced by including more elaborate descriptions. For instance, the book could give hints about the environments and describe the features or the animals in more detail.
• The students with multiple disabilities did not appear to be very engaged by the "Creature's Features" book. When teachers demonstrated it to them, they did not look at the pages.
• The students with multiple disabilities did not appear to pay much attention to the sample plastic animals that the facilitator distributed.

Social Interaction

• Many students with multiple disabilities appeared to need their teachers' assistance to participate in the activity.
• The activity did not afford much interaction among students.

Summary

The changes that were made in this activity (using a colorful, tactile book with audio descriptions instead of line drawings to represent the creatures, and showing children plastic animals to support discussion of how these animals are adapted to their environments) showed mixed results. None of them facilitated students' writing, with which nearly all students struggled. The availability of plastic animals in and of themselves did not appear to increase conversations about animal adaptations. The "Creature's Features" book was well received by the students with learning disabilities, who appreciated the colorful images and the availability of audio description. Students and teachers struggled to some extent with using the pen to make the audio descriptions play, and teachers of students with multiple disabilities suggested that the book could be enhanced by using larger font sizes and amplification of the audio descriptions. The response of the students with multiple disabilities to the "Creature's Features" book was less clear. Few, if any of them, were able to use the book on their own, and they did not demonstrate much interest in it.

Future changes in the activity must focus on either supporting students' writing or providing them with alternatives to express their thoughts about the environments in which the creatures are living (e.g., describing their ideas verbally, or using assistive technology such as GoTalk). Additional changes could focus on creating versions of the activity that incorporate more student interactions as well as guidelines that give suggestions for teachers on how to facilitate this activity (e.g., how to lead discussions about how an animal's features relate to the environment it lives in).

5. Blueprint for a Beast

Students' and Teachers' Responses to the Original Activity

Physical Interaction with the Activity

• All students with learning disabilities were able to create some representational drawings, even though they differed in the number of details they included.
• Students with multiple disabilities had issues with fine motor/grapho-motor control, which limited their ability to draw.
• Teachers offered multiple suggestions for improving the physical accessibility of the activity:

- Give students pre-drawn parts that they can assemble.
- Give students a choice of creatures to glue into an environment.
- If students can't draw, give them a picture and have them point to a body part.

Cognitive Engagement with the Activity

• A small number of students with multiple disabilities (2–4; mostly girls) gravitated to this activity.
• Most students with learning disabilities were engaged in this activity; 2–3 students took some time to start drawing.
• Some students with learning disabilities drew creatures only; others also drew their environment.
• While students with multiple disabilities paid sustained attention to the task, none of them was able to create representational drawings.
• Teachers' suggestions for improving the cognitive accessibility of the activity included:

- Keep creatures real (e.g., fish in the ocean).
- Use environments with which students are familiar (e.g., they may not know what an iceberg or volcano is).

Social Interaction

• Students with multiple disabilities were joined by some of their teachers, who gave them directions and helped them write their names and responses.
• The teacher of students with learning disabilities assisted them by talking to each student, asking them about the environment they chose and writing it down on their worksheet, and by asking questions about the creature and how it functions in the environment. She also asked some students to share what they drew with the whole group.

• Teachers suggested facilitating the activity with guiding questions (e.g., What would I need if I lived in water?).

Students' and Teachers' Responses to the Adapted Activity

Physical Interaction with the Activity

• Some students with learning disabilities used a variety of materials (wiki sticks, clay) to create animals in 3-D.
• The pictures that the facilitator used to show sample environments to students with multiple disabilities (e.g., desert, side of a cliff) were very small, and were difficult to see from the back of the room.
• Teachers of students with multiple disabilities had to assist their students in various ways to participate in the activity. In some instances, the teachers did the entire activity (e.g., create a 3-D representation) for the student. In other cases, teachers assisted students by guiding their hands while drawing, or helping to roll clay.

Cognitive Engagement with the Activity

• Several students with learning disabilities (all girls) engaged in the creating 3-D versions of the creatures with the art materials supplied.
• Some students with learning disabilities did not fully understand the instructions for this activity, and drew pictures from the "Where the Weird Things Are" activity.
• The teachers of students with multiple disabilities were engaged in the reading of the Eric Carle book.
• It was difficult to gauge how engaged the students with multiple disabilities were in the reading of the Eric Carle book. Some of the students did not look up when the instructor showed the pictures. The teachers did not prompt their students to look.

Social Interaction

• The teachers of students with multiple disabilities tried to engage their students in the activity as they assisted them by asking questions such as, "What color pencil would you like to use?" "What should I draw?" "What else does the creature have?" and "Do you want to use a different color?"
• Students with multiple disabilities did not share their creations with the group.

Summary

The changes made in this activity (the use of the Eric Carle book, the supply of a greater variety of arts materials, asking students to share their animals with the group) met with mixed success. The greater variety of materials increased the physical accessibility of the task, but did not appear to increase the cognitive engagement with it. Girls appeared to be more attracted to both versions of the activity than were boys. The Eric Carle book was successful with the teachers of students with multiple disabilities, but it was not clear if it had any impact on their students. The students did not share much about their creations, and the activity prompted little discussion about their animal's adaptation to the environment.

Additional changes could focus on creating versions of the activity that incorporate more student interactions as well as guidelines that give suggestions for teachers on how to facilitate students' cognitive and social engagement with this activity (e.g., how to facilitate an exchange of ideas regarding animals' features and their relationship to the environment they live in).

Summary and Conclusions

Overall, we found that student participation and engagement in the five Kinetic City activities was high, regardless of students' disabilities. The adaptations that were made in the activities were successful in improving their accessibility, at least for some students. However, some access issues remained. For instance, the writing activity remained inaccessible to students with both learning and multiple disabilities. In some instances, students were not fully aware of the existing adaptations (e.g., the availability of keyboard controls, or how to use the talking pen with the "Creatures Features" book), which limited their use of these adaptations. In another instance, we observed that an adaptation that improved access for some students created new obstacles for other students (i.e., the digital scale used in the revised Dunk and Flip activity was difficult to read for students in wheelchairs because of their angle of vision). These findings highlight the importance of conducting multiple iterations of user testing, the need for making students aware of access options, and the need for multiple versions of learning activities.

Our observations also highlight the importance of adults in mediating learning activities, particularly for students with more severe disabilities. Teachers, program leaders, and other adults working with students with disabilities need instructions for how to effectively facilitate the activities for students with different kinds of disabilities in ways that encourage students' independence and that promote physical, cognitive, and social engagement.

References

Reich, C., Price, J., Rubin, E., & Steiner, M. A. (2010). *Inclusion, disabilities, and informal science learning.* Washington, DC: Center for the Advancement of Informal Science Education (CAISE).

Appendices

1. **Parental Consent Forms**
2. **Teacher Consent Forms**
3. **Teacher Interview Protocol**

Appendix 1: Parental Consent Forms

Education Development Center, Inc.

Parent/Guardian Permission Form
Kinetic City Empower Research Study

The Education Development Center, Inc. (EDC) is a nonprofit research and development organization dedicated to improving the quality, effectiveness, and equity of education. The American Association for the Advancement of Science (AAAS), is an international non-profit organization dedicated to advancing science around the world by serving as an educator, leader, spokesperson and professional association.

Purpose of the study: We are conducting research to develop Science, Technology, Engineering, and Mathematics activities that can be used by students with disabilities. The study is funded by the National Science Foundation.

Description of the Research: This study will take place at your child's school. Participants will try out five science activities developed by AAAS. We will do the activities over two two-hour sessions. To understand more about students' interests in science, technology, engineering, and mathematics; and to learn students' opinions about the science activities; we plan to do interviews or ask students to respond in writing to questions, whichever format they prefer. Each interview or written response session will take about 10 minutes during each of the four sessions. Interviews will be audio recorded and transcribed. This study will not result in a decrease in instructional time.

Benefits: Your child may benefit by enjoying the activities, and his or her responses will contribute to efforts to make the science activities more accessible for students with disabilities.

Risks and Confidentiality: The data from this study will remain confidential. Participation will involve minimal risk associated with breach of confidentiality. We will make every effort to minimize this risk. Audio recordings from the interviews will be transcribed and audio files will be deleted at the end of the study. Audio recordings and transcripts will not contain your child's name, and will be accessible to research staff from EDC and AAAS only. Interview statements may be quoted in the final evaluation report, but participants will not be identified by name or described in such a way that they can be identified. The results of the study, and therefore excerpts of interviews, may be presented at scientific meetings and in published reports for educational, policy and scientific purposes. Upon your request, you will be informed about the results of this study.

Costs and Compensations: It will not cost your child anything to be in the study. Your child will receive a $25 gift card at the completion of the four sessions.

Your Rights: Participation in this research is strictly voluntary. Your child is free to not answer any question they choose not to. Should your child choose to discontinue his/her participation in the study, he/she can withdraw at any time without penalty or loss of benefits after signing this form. Parents please be aware that under the Protection of Pupil Rights Act. 20 U.S.C. Section 1232(c)(1)(A), you have the right to review a copy of the questions asked of or materials that will be used with your students. If you would like to do so, you should contact Babette Moeller at (800) 225-4276 ext 4205 to obtain a copy of the questions or materials. You may also use this number to contact Babette Moeller if you have any other questions about the research. If you have any questions regarding your rights as a participant in or concerns about this research, you can contact EDC's Human Protections Administrator at 1-800-225-4276 ext. 2971 or HumanProtections@edc.org.

You will receive an extra copy of this permission form for your records.

_____Yes, I agree to have my child participate
_____No, I do not give consent for my child to participate

______________________________ ______________________________
Your Child's Name (please print) School Name (please print)

____
Name (please print)

______________________________ _______________
Signature Date

96 Morton St. ● New York, NY 10014 ● Phone: 212.807.4200 ● Fax: 212.633.8804 ● www.edc.org

Education Development Center, Inc.

Parent/Guardian Permission Form
Kinetic City Empower Research Study

The Education Development Center, Inc. (EDC) is a nonprofit research and development organization dedicated to improving the quality, effectiveness, and equity of education. The American Association for the Advancement of Science (AAAS), is an international non-profit organization dedicated to advancing science around the world by serving as an educator, leader, spokesperson and professional association.

Purpose of the study: We are conducting research to develop Science, Technology, Engineering, and Mathematics activities that can be used by students with disabilities. The study is funded by the National Science Foundation.

Description of the Research: This study will take place after school at your child's school. Participants will try out five science activities developed by AAAS. We will do the activities during two one-hour sessions. To understand more about students' interests in science, technology, engineering, and mathematics; and to learn students' opinions about the science activities; we plan to do interviews or ask students to respond in writing to questions, whichever format they prefer. Each interview or written response session will take about 10 minutes during each of the two sessions. Interviews will be audio recorded and transcribed. This study will not result in a decrease in instructional time.

Benefits: Your child may benefit by enjoying the activities, and his or her responses will contribute to efforts to make the science activities more accessible for students with disabilities.

Risks and Confidentiality: The data from this study will remain confidential. Participation will involve minimal risk associated with breach of confidentiality. We will make every effort to minimize this risk. Audio recordings from the interviews will be transcribed and audio files will be deleted at the end of the study. Audio recordings and transcripts will not contain your child's name, and will be accessible to research staff from EDC and AAAS only. Interview statements may be quoted in the final evaluation report, but participants will not be identified by name or described in such a way that they can be identified. The results of the study, and therefore excerpts of interviews, may be presented at scientific meetings and in published reports for educational, policy and scientific purposes. Upon your request, you will be informed about the results of this study.

Costs and Compensations: It will not cost your child anything to be in the study. Your child will receive a $25 gift card at the completion of the four sessions.

Your Rights: Participation in this research is strictly voluntary. Your child is free to not answer any question they choose not to. Should your child choose to discontinue his/her participation in the study, he/she can withdraw at any time without penalty or loss of benefits after signing this form. Parents please be aware that under the Protection of Pupil Rights Act. 20 U.S.C. Section 1232(c)(1)(A), you have the right to review a copy of the questions asked of or materials that will be used with your students. If you would like to do so, you should contact Babette Moeller at (800) 225-4276 ext 4205 to obtain a copy of the questions or materials. You may also use this number to contact Babette Moeller if you have any other questions about the research. If you have any questions regarding your rights as a participant in or concerns about this research, you can contact EDC's Human Protections Administrator at 1-800-225-4276 ext. 2971 or HumanProtections@edc.org.

You will receive an extra copy of this permission form for your records.

_____Yes, I agree to have my child participate
_____No, I do not give consent for my child to participate

______________________________ ________________________________
Your Child's Name (please print) School Name (please print)

____
Name (please print)

______________________________ _______________
Signature Date

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Appendix 2: Teacher Consent Forms

Education Development Center, Inc.

Teacher Interview Consent Form
***KC Empower: Universal Access to After School STEM* Research Study**

The Education Development Center, Inc. (EDC) is a nonprofit research and development organization dedicated to improving the quality, effectiveness, and equity of education. The American Association for the Advancement of Science (AAAS), is an international non-profit organization dedicated to advancing science around the world by serving as an educator, leader, spokesperson and professional association.

Purpose of the study: We are conducting research to develop Science, Technology, Engineering, and Mathematics activities that can be used by students with disabilities. The study is funded by the National Science Foundation.

Description of the Research: The research involves interviews with teachers of children with disabilities to learn about their students' interests in Science, Technology, Engineering, and Mathematics (STEM), and about whether adapted versions of five STEM activities are accessible for youth with disabilities. As part of this study, and with your permission, you will participate in up to two brief interviews during two activity sessions that will take place at your school. Each interview will take about 15 minutes. The interviews will be audio-recorded.

Benefits: You may benefit by helping to make the STEM activities more accessible for students with disabilities.

Risks and Confidentiality: The data from this study will remain confidential. Participation will involve minimal risk associated with breach of confidentiality. We will make every effort to minimize this risk. Audio recordings from the interviews will be transcribed and audio files will be deleted at the end of the study. Audio recordings and transcripts will not contain your name, and will be accessible to research staff from EDC and AAAS only. Interview statements may be quoted anonymously in the final evaluation report, but participants will not be identified by name or described in such a way that they can be identified. The results of the study, and therefore excerpts of interviews, may be presented at scientific meetings and in published reports for educational, policy and scientific purposes. Upon your request, you will be informed about the results of this study.

Costs and Compensations: It will not cost you anything to be in the study. Your school will receive a $25 gift card at the completion of the four sessions.

Your Rights: Participation in this research is strictly voluntary. You are free to not answer any question you choose not to. Should you choose to discontinue your participation in the study, you can withdraw at any time without penalty or loss of benefits after signing this form. If you have any questions about this research, you can contact Babette Moeller at (800) 225-4276 ext. 4205 to obtain a copy of the questions or materials. If you have any questions regarding your rights as a participant in or concerns about this research, you can contact EDC's Human Protections Administrator at 1-800-225-4276 ext. 2971 or HumanProtections@edc.org.

You will receive an extra copy of this consent form for your records.

_____Yes, I agree to participate
_____No, I do not wish to participate

_______________________________ _________________________________
Name (please print) School Name (please print)

________________________________ ________________
Signature Date

21

96 Morton St. ● New York, NY 10014 ● Phone: 212.807.4200 ● Fax: 212.633.8804 ● www.edc.org

Teacher Interview Consent Form
***KC Empower: Universal Access to After School STEM* Research Study**

The Education Development Center, Inc. (EDC) is a nonprofit research and development organization dedicated to improving the quality, effectiveness, and equity of education. The American Association for the Advancement of Science (AAAS), is an international non-profit organization dedicated to advancing science around the world by serving as an educator, leader, spokesperson and professional association.

Purpose of the study: We are conducting research to develop Science, Technology, Engineering, and Mathematics activities that can be used by students with disabilities. The study is funded by the National Science Foundation.

Description of the Research: The research involves interviews with teachers of children with disabilities to learn about their students' interests in Science, Technology, Engineering, and Mathematics (STEM), and about whether adapted versions of five STEM activities are accessible for youth with disabilities. As part of this study, and with your permission, you will participate in up to two brief interviews during the two activity sessions that will take place afterschool. Each interview will take about 15 minutes. The interviews will be audio-recorded.

Benefits: You may benefit by helping to make the STEM activities more accessible for students with disabilities.

Risks and Confidentiality: The data from this study will remain confidential. Participation will involve minimal risk associated with breach of confidentiality. We will make every effort to minimize this risk. Audio recordings from the interviews will be transcribed and audio files will be deleted at the end of the study. Audio recordings and transcripts will not contain your name, and will be accessible to research staff from EDC and AAAS only. Interview statements may be quoted anonymously in the final evaluation report, but participants will not be identified by name or described in such a way that they can be identified. The results of the study, and therefore excerpts of interviews, may be presented at scientific meetings and in published reports for educational, policy and scientific purposes. Upon your request, you will be informed about the results of this study.

Costs and Compensations: It will not cost you anything to be in the study. Your school will receive a gift card at the completion of the study.

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_____Yes, I agree to participate
_____No, I do not wish to participate

______________________________ ______________________________
Name (please print) School Name (please print)

______________________________ _____________
Signature Date

Appendix 3: Teacher Interview Protocol

Teacher Interview Questions

Goals:
1. To learn about your students' interests and preferences for afterschool STEM activities.
2. To obtain input about the appeal and accessibility of selected KC Empower activities.

1. Students' Interest and Experiences in Afterschool Science Programs
Have you engaged in STEM activities with your students who have disabilities? What are your thoughts about their ability to fully participate? What do you think would make STEM more exciting for students with disabilities (probe for content/topics, types and level of activities)?

What interests your students, especially those with disabilities, about Science, Technology, Engineering and Mathematics (STEM)?

What topics/content are they interested in?

What STEM activities do they like?

What do they NOT like?
What kinds of technology do your students like to use?

What are barriers that may get in the way of your students' technology use?

What are your suggestions for resolving this issue?

What kinds of difficulties might students with disabilities come across in afterschool or summer STEM programs?

What suggestions do you have for making afterschool or summer STEM programs more accessible for students with disabilities?

2. Students' Responses to KC Empower Activities

How did you like the activity? How do you think students will like it?

How would you use the activity in your program?

How easy or difficult do you think it will be for students with disabilities to read and follow the instructions?

How easy or difficult do you think it will be for students with disabilities to do the activity?

What do you think students will learn from the activity?

How could the activity be changed to make it more interesting for students with disabilities (probe for presentation of the activity, content/topics, types and level of activities)?

How could the activity be changed to make it more usable/accessible for students with disabilities?