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# Designing Opportunities to Spark and Nurture Scientific Inquiry in Middle School Girls

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**Abstract**

Our project, Click! Urban Adventure, was designed to immerse middle school girls in an interactive, mixed-reality game that provides them with the tools they need to learn discipline-specific science, technology, engineering, and mathematics (STEM) skills. The 11 to 14 year old girls who participated in Click! used the city as their game board and STEM components as their tools. As part of the game, the girls take on the role of Click! Special Agents as they think, talk and reason their way towards solving an environmental science-based mystery.

Our research team worked carefully to reshape the conventional framework of formal education and apply it to the landscape of everyday experiences. Click! was designed to show middle school girls, often underrepresented in science and technology, that understanding the world through a scientific lens can be stimulating, relevant, contextual and rewarding [2].

**Keywords**

Games, Interaction Design, Interdisciplinary Design, User-Centered Design, Live Performance, Visual Design, Children, Augmented Reality.

**Problem Statement**

In the spring of 2004, we began to develop and design narrative-driven, non-digital games that made science

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and technology accessible to middle school girls. Over the course of five months we worked with approximately 200 girls from diverse backgrounds to identify several key design resources that could be used to interweave the existing interests of the girls into the product. These resources include: immersion /experience, seeing/inquiring, identifying/discovering, and action/environment. Our primary goal was to design an authentic, sustainable learning culture within the boundaries of a game [5,6,7].

## **Background**

### *Development Team*

Our development team was comprised of designers, interaction designers, informal educators, writers, computer scientists, social scientists, and middle school teachers. Our core group planned project activities according to the perceived needs for research, conceptualization and initial development. We created many activities that fostered learning and personal growth for both the students and the project developers.

### *Context*

Click! was designed for middle school girls to encourage greater involvement in science, technology, engineering, and mathematics (STEM) activities that will enhance classroom achievement and, ultimately, increase diversity in the STEM workforce. For girls growing up today, STEM skills will be important for self-sufficiency, as a technology-driven economy increasingly demands a workforce competent in STEM. One of the reasons women are underrepresented in STEM educational programs and workforce may be the continued cultural stereotype that STEM activities are intellectually out of reach of and inappropriate for girls

and women (Bleeker & Jacobs, 2004; Eccles & Jacobs, 1986). While girls consistently demonstrate an aptitude for both math and science, their interest in math and science is often discouraged, either implicitly or explicitly. For example, media reports of Benbow and Stanley's 1980 study, claiming that "there is a math gene and boys have it," led the general public to lower their estimation of girls' abilities in this field. Such negative stereotyping unfortunately continues to discourage females from pursuing these topics of study in school and seriously considering future careers that require advanced related skills (AAUW, 2000; National Council for Research on Women, 2001). Click! was designed to give middle-school girls a positive and alternative vision of women and technology.

### *Project dates and duration*

Game development took place during the spring and summer of 2004 in classes taught at Carnegie Mellon University and the University of Pittsburgh. These classes were as follows:

- Carnegie Mellon School of Design, course title: "Click! The Urban Adventure." This course used design research to develop and test game concepts and themes with girls.
- Pittsburgh Teachers' Institute, a seminar for Pittsburgh Public School Teachers. This seminar worked closely with the design team to explore city landmarks from a variety of perspectives, including: history, geology, ecology, culture, politics and sociology.
- University of Pittsburgh, course title: "School's Out! Designing and Using Informal Learning Environments in Science." Students in this course developed specific science-related tasks to be used in the game.

## Process

The design process can be divided into two phases: early user research and design/testing. In the first phase we conducted ethnographic research into the popular culture of teenage girls [8]. This helped us determine the essential verbal and visual features that would ensure general applicability and audience enjoyment of the games we developed. In our second phase, we conducted research on concept ideation, concept validation, prototype development (including visual identity), content development, software, and interaction and game design [5,9]. Various games were designed and tested for the intended audience.

### *Early user research*

Our early research focused on the interests and culture of teenage girls. We learned what girls were responding to in the popular culture. Most popular were character-driven video games, movies, television shows, and web sites. The girls were particularly interested in scenarios that portrayed women as lead characters, in roles such as scientist, mathematician, secret agent, or crime science investigator, involved in an action-filled episode within their home city. We observed that it was very important to the girls to connect personally with a character. The girls saw that the characters with which they identified also had problems with relationships, conflicts with family and friends, and managing issues of identity. In all cases the characters were out in the world solving crimes and improving the well-being of society. This personalization and identification was important to our conception of the game we would develop. We began to further investigate various types of educational games, such as MIT: Games to Teach,



Recent television shows like CSI, Alias, and Law and Order have successfully begun to change the perception of the role of the female scientist. Female characters like Sydney Bristow of Alias are portrayed as confident, smart, and equipped with the knowledge and tools to solve problems in any situation [10].

Playground Collective, B.U.G. (Big Urban Game), and Gamelab [11,12,13].

We spent two weeks observing middle school girls and boys in both private and public school settings. This research provided the following observations:

- Girls worked together, talking to each other and shouting out answers. While distracting at times, they shared a spirit of teamwork and friendship.
- Girls readily went to the whiteboard to work out problems and present their answers. They felt comfortable standing in front of their peers working on a problem for a long time. Some of them, after completion, would sign their names or write brief comments, personalizing their answers.
- The boys were much more restrained. They seemed to understand the material very well, but had little interest in group activities.
- When there was open discussion, boys were the first to raise their hands and usually the first to be called on to give answers.
- Girls used stickers and buttons to personalize their notebooks, book-bags and clothing.
- Brand name clothing and accessories were very important to girls but not to boys.
- In most cases girls would add diagrams or pictures to the margins of their classroom notes to help work out an answer, indicating to us that they are both visual and verbal learners.

Our team used this knowledge to develop a series of non-digital, narrative-based mystery games that were tested over a span of five weeks with twenty middle school girls in an after school program at a local community center. We also used the time to conduct

personal interviews, observations, and questionnaires to validate early research, test our assumptions on the type of games that would be of interest to the girls, and further learn about their interests.



**Figure 1.** Lead character before role-playing was introduced into the game



#### *Prototype of Non-Digital Game*

The girls were given 11"x17" sheets of paper that served as a game board. On the board there were several places to write or sketch ideas about the story as they came to mind. In the course of our testing, we found one narrative to be particularly instructive. This was based on several "bad industrialists" who wanted to out-produce and out-smart all of their competitors by using a device called the "weather controller." They would use this device regardless of the significant environmental damage it would cause. The clues in the story were designed to lead the girls to the "weather controller," which they had to destroy before the evildoers could overrun the environment with waste. Although our narrative was designed using real environmental issues, the fictitious characters and unbelievable plot overshadowed the girls' abilities to immerse themselves in the play experience, and they lost interest quickly.

Using the same group of girls, we then used the same narrative but asked the girls to imagine themselves as special agents who had been charged with the task of finding the "weather controller." Because in the first round of testing the girls spontaneously introduced the idea of tools, we decided it would be interesting to promote this concept in a more realistic context. We asked each girl to select an agent name, the outfit she would wear, the tools she needed to be successful in the current scenario, and the places she would visit during the mission. Tools selected by an agent might be

a cell phone, laptop, pencil, notebook, clothing or accessories. We gave each girl illustrations of the items she had chosen, which were then attached to her game board as a reminder of the resources she could use in solving the problem. By role-playing as agents they began to see themselves as problem seekers and solvers. In the process of creating their agent profiles they began to share with us, through conversation and visual storytelling, what they personally would do as agents. However, the idea of the "weather controller" still remained unbelievable. The girls could not accept that a device could actually change weather patterns. They felt that such things are only seen on television, not in real life.

These studies demonstrated the features necessary to hold the attention of the players: the story had to be convincingly realistic, the girls had to be actively participating in the story, and the educational content had to be woven into the story [2].

#### *Early Research, Second Phase*

In order to learn more about narrative-based mysteries we conducted a second round of research. The goal of this early research was to explore how we could create a science-based mystery that addressed STEM issues while maintaining authenticity of the story and creating a believable experience for the participants.

In our first effort, we designed a narrative-based mystery game called the Cream Pie Mystery. For one week we operated a booth at the local Science Center's Science and Technology Festival, offering attendees the opportunity to play the game. Participants were told that someone had stolen the secret recipe for banana cream pie that would not spoil. The game had two main

features embedded in the story: role-playing and science-related tasks. The players were a diverse group of over 200 middle school boys and girls. They were asked to role-play as forensic scientists analyzing animal hair, extracting fruit DNA, conducting chromatographic analysis, and using Global Positioning Satellites and deductive reasoning. The players were asked to select a name, job title, special skills, and tools that might be needed to solve the crime.



**Figure 2a.** Inside Science Center, analyzing fruit DNA.



**Figure 2.** Group of girls using GPS to find the guilty suspect at the Science Center.

#### *Assessment*

At the conclusion of the Cream Pie Mystery test we examined what we had learned. We observed that the kids enjoyed participating in science-oriented tasks while role-playing. Even though our story was based on fictitious animal characters, the kids were still able to immerse themselves in the story and assume roles and take on tasks to solve the mystery. The kids used the

experience to experiment with roles they might never have tried, expanding their perceptions of themselves. We observed that, although we designed the game to be played by individuals, the girls played all aspects of the game collaboratively. They designed hypotheses together and guided each other through the science labs. The male participants were very different in their approach – not sharing their answers, trying to be the first to participate, and instilling a competitive aspect into the game. When girls and boys played together, girls assumed the role of “note taker”. Often boys would do the experiments, hand dirty test tubes to their female counterparts to dispose of, dictate the results, and move on to the next task. At the end of the game when we asked what was learned and who might have committed the crime, most girls were not able to follow the storyline because they were doing task-specific activities during the game, not contributing or participating in the experience as a whole.

#### **What we learned**

This research led us to conclude that the following features were necessary to encourage girls to participate in STEM-related tasks:

- Creating a subculture for “girls only”
- Building peer groups of friends (girls) to create a team-based experience and opportunities for social exchange
- Including role-playing and opportunities for girls to project future plans and dreams
- Giving individual and group rewards for achievements
- Creating opportunities to learn how to talk and write about science and technology

- Using existing interests as leverage to discover new areas of interest in STEM

*Designing a mixed reality game to accommodate desired learning goals*

The developmental path for this project involved the creation of numerous prototypes, which have taken the form of card games, game boards, live action scenarios, and interactive screens. Along the way, story telling and role-playing have emerged as vital components in connecting the project's multiple goals. An examination of these features in a game context helps to provide unique insights into how to create an authentic experience while providing a rich learning experience for girls [1,7,9].

For the final product, we chose to create a live action mixed-reality game. The narrative gives the girls a role, provides context for what they are doing, and motivates them to create their own path between locations where they may find important clues and meet characters. In the end, the story is primarily created by the girls' interactions with the game elements.

Once the initial plot was developed, it was transferred into game rules, structure, locations, clues, and characters. The key objective was that the game experience should serve as a catalyst to encourage girls to participate in science and technology. Designing a game system that anticipated moves, encounters, and interactions with clues, characters, and locations was one of the main challenges. The game and all of its component parts had to be situated in a real-world city environment that already has its own set of rules and restrictions. The goal became to weave the fictional

story into the real world fabric in such a way that the game elements were identifiable without being extraneous, striking a delicate balance that kept the girls from being pulled out of the game. This meant that locations needed to work not only logistically within the city map so the girls could walk from one place to another, but also within the narrative so that it made sense to go from one place to another. The conclusion of the game also needed to support the scientific approach: gathering and analyzing data and forming hypotheses.

*Product testing the narrative and science content*

Over the course of several months we developed and tested our first live action game. We ran the game in July of 2004, with sixteen girls playing in teams of four. The story revolved around the kidnapping of a rock star (and Click! agent) named Roxy Robin. Roxy was kidnapped because she had discovered that somebody was polluting the rivers with their land development projects. To get Roxy back, the girls had to collect evidence, which involved analyzing the pH of soil, computing the speed of a van, and interrogating suspects. The test went well, and in general the girls liked the story. However, when we attempted to expand this story to something that could support multiple teams playing at one time, we began to understand some of the limitations in our chosen narrative.

Focusing on a crime like kidnapping made expansion difficult, since the conclusion of the game required a physical feat instead of a scientific one. Additionally, kidnapping stories are essentially linear – you follow a trail until you find the person. This made it difficult to accommodate alternative choices within the narrative



**Figure 3.** (Excerpt from the handbook)

Every Click! girl is different, and that's a good thing. If every member of a Click! team thought the same way, they wouldn't have nearly as many skills on hand to catch the bad guys (plus they'd be really boring). Since people first started trying to figure out the world around them, girls and women have been right there along with the men, making discoveries and pushing the limits of science. Because they didn't get much support from the boys, these girls formed their own society: Click!

Today Click! members (called agents) use their knowledge of science to make the world a better place. Because nobody expects a teenage girl to be a scientific and criminal expert, they can sneak under the radar to find the truth. This is why they can help solve mysteries that the police or FBI can't figure out. There are as many kinds of Click! Agents as there are mysteries to solve. What kind of Click! Agent are you?

that were still vital to the story and important to the overall solution. We didn't want to create a story with only one path and one answer. Another problem was the role-playing aspect in this scenario. Although we created several personas the girls could assume under the CSI (crime scene investigation) umbrella (forensic specialist, cryptographer, sketch artist), their preconceived understanding of what a crime scene investigator was overshadowed their ability to immerse themselves in a specific character equipped with specific tasks and tools.

#### *How we moved forward*

Our solution was to rewrite the story so that the science focused around a current environmental issue – water quality. This meant that the science tasks the girls would perform in the course of gathering evidence – earth science, forensic science, mapping and document analysis – would all build to a bigger idea that involved understanding environmental science, physics, and engineering.

### **Solution**

*Designing an authentic experience: The Click! Agency*

Our iterative process has helped us understand that the new game subculture that we create for the girls has to compete with the popular culture they currently participate in. Our success to date has been due to our ability to creatively decode, analyze and conceptualize this problem at every stage of product testing [8]. It was our intent to have girls perceive Click! as an actual place with a history and a future. The notion of an actual Click! Agency allows girls to form an image of women, girls, and science that is ongoing and hopefully inspiring. It also allows girls to take on the role of special agents in the context of a larger community of

women who use science and technology to solve problems. We worked to establish a history and personality for the Click! Agency in a few different ways. These included a handbook and profile quiz, agency training, use of characters, and the Urban Adventure.

#### *Handbook and profile quiz*

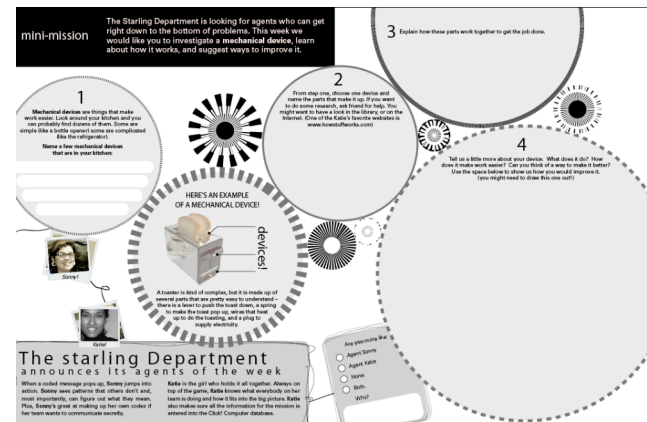
In one example of recruitment material used to invite girls to join Click!, girls are asked to take a personality quiz to see if they are “Click! enough” to be a member of the agency.

#### *Agency Training, Departments and Roles within Click!*

Agency Training offered extensive exposure to discipline-specific STEM. It took place during after-school Click! Club meetings in the month preceding the adventure game and introduced the girls to science and technology in the context of real world situations. While training was necessary to provide the girls with specific skills they needed to play the game, it was also intended to reinforce the idea that STEM play a vital role in our everyday lives. Training emphasized role-playing and provided an opportunity for skill development and task completion. The role-playing tools were designed to encourage the girls to see and build upon their unique individual skills. In addition, agency training provided the girls the experience of a friendly atmosphere in which they could create a “girl science community.”

We started training by letting the girls know that the agency was currently hiring and had positions open in various departments. A Senior Agent then interviewed each girl, insuring they were a good fit for the organization. The training sessions provided girls an

opportunity each week to “try on” a new role within a department. We designed a series of take-home “mini-missions” for each week that highlighted key departments, outstanding Senior Agents, and past cases where Agents have used their individual skills. The mini-mission contained science-related lessons and activities based on the training topic for the next week. The mini-missions also served as a reminder of how the girls used science and technology every day.



**Figure 4.** Mini-mission designed to highlight the Starling Department and complement week three of training. Starlings are agents who can “get down to the bottom of problems”. Agents were asked to investigate a mechanical device in their home, learn about how it works and suggest ways to improve it.

Part of teaching the girls how to build a Click! Agent Profile was helping them understand their own unique qualities and allowing them, through role-playing, to see themselves in ways they may never have envisioned. Details of the role, tools they might use, and special qualities that make each role interesting were given to the girls in the form of flashcards. During

training and during the game they were encouraged to anticipate what skills they might need based on the specific scientific tasks they might encounter. Here is an example of a description of the Hummingbird Department: *“Cool and composed, they may not say much, but they see everything. The department is looking for girls who are careful observers, who make sure to get all the facts about a situation before making a move. With their brains and insight, they can piece together all the clues to find out the truth behind a crime”*. A persona or role within the Hummingbird Department might be a forensic specialist. The forensic specialist sees the clues that others miss. A fingerprint, a piece of thread, a strand of hair – none of these escape her notice because she understands how these small things can carry loads of information. She also makes sure that all the information from a clue gets entered into the Click! Computer so the details don’t get lost. Another role in the department might be the Profiler. The profiler uses handwriting analysis, lie detection skills and interrogation techniques to get to the truth. When the team finds a note or talks to a witness, she is able to figure out what is fact and what is fiction. She looks at the suspects’ motives and matches them with the evidence to build a case.

#### *Use of characters in the game and in training*

Throughout the game and training girls were in contact with over 30 actors, each playing a part to help create an authentic experience for the girls. Some of the characters were hired actors playing a suspect or witness, while others were members of our research team evaluating and assessing the girls.

The first fictitious Senior Click! Agent we created was Roxy Robin, who played a role in Agency Training and



the Adventure Game. She served as a role model and the personification of Click! In addition to being a Click! Agent, Roxy was the lead singer for a band, The Songbirds. She developed an interest in water quality issues and joined a local group called "Swim the Rivers" after her father got sick from contaminated water. Her parents are divorced and she struggles with relationships and schoolwork. This information was communicated to the girls through Roxy's web site, where they could read her weblog. Roxy helped to guide the game by sending text messages and making phone calls, and she and her band were also a physical presence during the game. They moved through the game space, and teams that came into contact with the band could solicit advice or help from them.



**Figure 5.** Roxy's blog on the web site Roxy Robin and the Songbirds ([www.thesongbirds.com](http://www.thesongbirds.com)) was the girls' first introduction to the mystery surrounding Combined Sewage Overflow (CSO).

#### *The Urban Adventure*

The culmination of the Click! experience is the Urban Adventure game. The game is played in teams of four

girls and a mentor, a female science student from a local university. Multiple teams play the game at the same time. Each team is provided with standard gear, including a laptop computer, mobile phone, barcode scanner, digital camera and GPS device. These devices are used throughout the game to communicate with other teams, retrieve clues and log evidence. The game begins when Roxy Robin calls for help in solving a mystery. The teams are briefed about the case, including locations and suspects, and then sent off to investigate. At the start of the game, each team is sent to a different location. After that, the teams move between locations based on the clues they find and their own intuition. At each location, the teams find clues to the mystery.

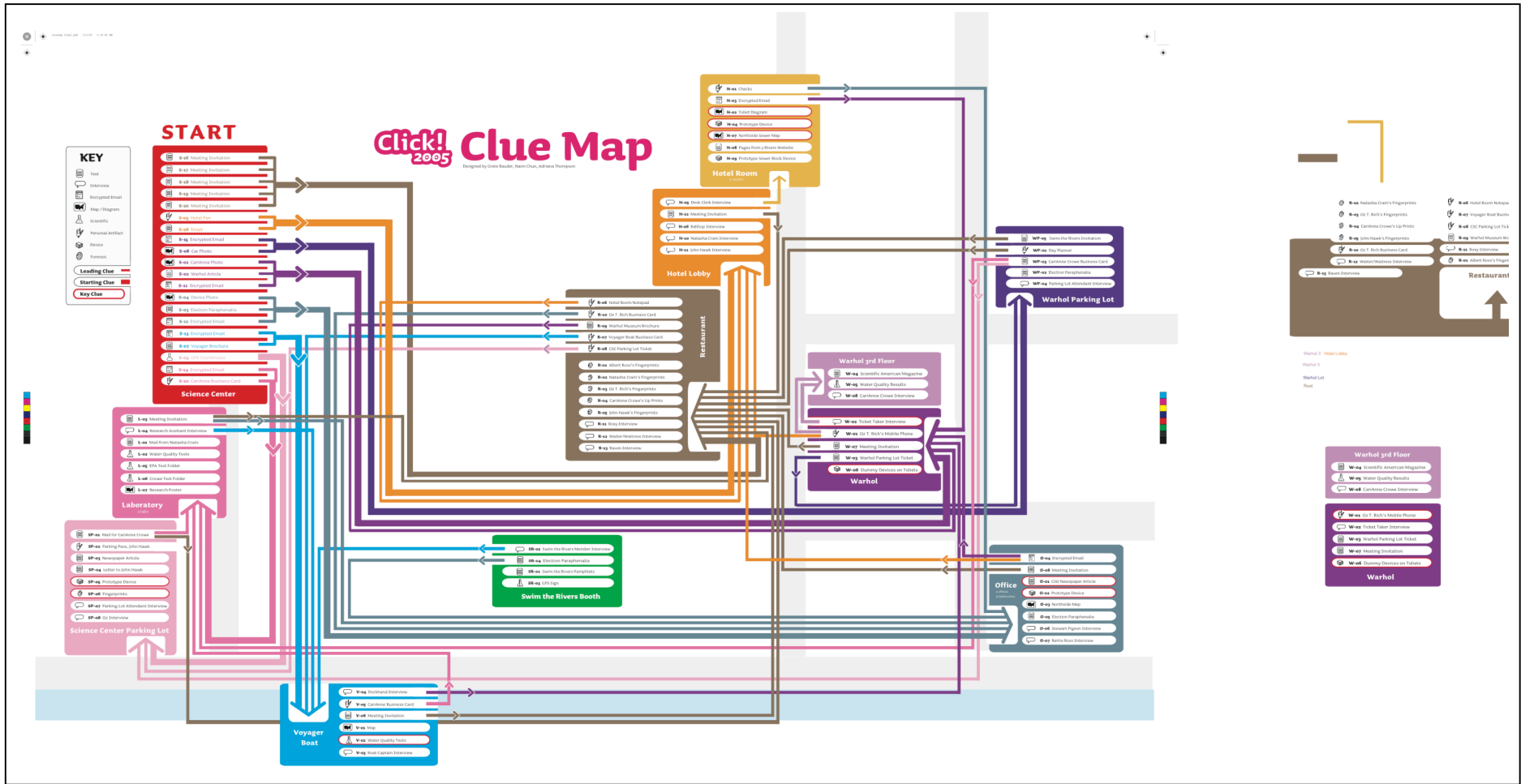
Clues are logged by being scanned, using a barcode scanner, into the Click! Database on the laptop computer. When a clue is scanned, a team can make notes regarding its importance and any theories they may have about its involvement in the mystery. In addition to clues, teams may also encounter different characters as they move around the game board. These characters may be suspects or they may be supporting characters providing information related to the story. These characters, and the information they provide, can also be logged into the Click! Database.



**Figure 6.** In the game economy girls are rewarded with Click! Cash to spend at the Gear Store or on other expenses. The gear highlights different types of technology and includes everything from measuring tapes to GPS devices.



**Figure 7.** Illustration highlighting girls' experiences during the game. Each team of girls was given clues that led them to various locations around the city. At each location girls could scan clues, interview witnesses, and interrogate suspects.



**Figure 8.** It was essential for the Click! Team to anticipate possible paths the girls might take in the game based on clues they discovered. Much like a wireframe used by interaction designers, the design of the Clue Map helped our team see the entire game space. An icon system was developed to indicate types of clues that could be found at each location and the number of girls a location could potentially support. The map also allows us to track and plot the actual paths the girls took during the game. We are able to see flaws in the narrative-based decisions, routes taken by teams, and time taken at each location by individual teams [5].



**Figure 9.** Visual interface, Click! Super Computer.

When all clues have been collected, the teams are called back to Click! Headquarters. Here they can interrogate suspects and analyze evidence as they create a Click! Case File. The case file details who is involved in the mystery, why they are involved and how the plot is being carried out. Each claim must be supported with evidence.

*Click! Urban Adventure in Pittsburgh, PA, an exemplar*  
The first full version of Click! Urban Adventure was run June 2005 in Pittsburgh, PA. Girls were recruited from all over Pittsburgh and 230 girls aged 11-14 signed up to participate. Eighty four girls signed on as Click! agents and were trained over a six week period. Of the participants, 86% came from public schools and 53% were minorities. There were 21 teams involved in the first live version of Click!. Prior to training the girls were asked about their previous knowledge and interest in STEM, characteristics of their friends, what it meant to them to be part a subculture like Click!, and their future aspirations.

### *Results*

Click! was successful in many ways. Girls interest in STEM was increased; girls recognized the importance of STEM to their education and futures; girls were inspired

to learn more about science and technology, and girls had positive associations to STEM material. At the conclusion of the Click! game 93% of the participants had a high degree of confidence in their ability to use technology. Seventy-eight percent of participants reported wanting to learn more about the technologies they encountered in the Click! experience. Girls incorporated scientific material during the game, with 63% reporting a scientific fact when asked if they had learned anything new about Pittsburgh. Another interesting result of the game was that girls got to experience themselves and their peers as successful at STEM skills and intelligent. Girls reported that they were impressed with “all the smart girls in Pittsburgh”. Girls specifically reacted to their peers’ knowledge of science, reporting that they were surprised by how much they knew. Click! was successful in seeding conversations about science. When asked, 95% of the girls had talked to their friends about Click! and 65% had talked to their parents about Click!. All of the participants and all of their parents reported wanting to be involved in Click! again.

### *Click! and the Design Process*

With the Click! Urban Adventure experience in Pittsburgh, we have seen the effects of a successful design intervention. So often, designers downplay their ability to successfully intervene in education, but using the design process to establish criteria for learning science has had amazing results. Working in the informal world is helping us teach kids alternative ways to think and arrive at solutions to problems.

### **Conclusion and Future Work**

Click! successfully engaged 11-14 year old girls in science and technology. Girls enhanced their skill and

sense of self-efficacy through their experience with Click!. It also offered designers and educators an opportunity in collaboration to solve a community problem. Further evaluation will look at the impact of Click! after six months time. It is important to find out whether Click! has had an impact beyond the weekend of the game. A product such as Click! creates opportunities for multiple partners with various interests to apply their ideas to the solution of practical problems.

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