

Front-end Evaluation of
BIOMEDICAL TECHNOLOGY PROJECT
for
The Great Lakes Science Center

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EXECUTIVE SUMMARY

Introduction: With a Science Education Partnership Award from the National Institutes of Health, the Great Lakes Science Center (GLSC) will update and expand its current *Medical Technology* exhibition to create a new exhibition on *Biomedical Technology*. Goals for the new exhibition include introducing visitors to biomedical technology (BMT), (i.e. the interdisciplinary application of physics, engineering, math, and biology to medicine); showing how BMT improves and saves lives; highlighting Case Western Reserve University's (Case's) cutting-edge research and application of BMT; and introducing participants to careers in BMT. Although the target age range for this project has been set at 7th and 8th grades, the team intends to develop an exhibition that effectively achieves its goals for the full range GLSC visitors.

Selinda Research Associates, Inc. (SRA) was contracted by GLSC to complete a front-end evaluation for the *Biomedical Technology* project. The research question for this front-end study was, "What can we learn about potential visitors' understandings of, and connections with, biomedical technology issues that will help the exhibition team develop an engaging and provocative exhibition?"

Methodology and methods: SRA used a naturalistic methodology to guide this study (Lincoln & Guba, 1985). Data collection included a literature review, observations and interviews with GLSC visitors, and interviews with GLSC staff. GLSC visitors were purposively selected to represent a broad range of interests and background knowledge in BMT. The analysis of these qualitative data was an on-going process using a modified inductive constant comparison approach (Lincoln & Guba, 1985). Knowledge hierarchies were developed to analyze the range of ways in which visitors thought and felt about the topics covered by this study.

Results: The meaning of biomedical technology. Adult respondents often guessed a fairly accurate definition of "biomedical technology" even though many said they were unfamiliar with the term "biomedical." Children up through middle-school age had difficulty making sense of the term. Respondents said they expected the exhibition to include both "cures" (i.e., the medical part) and something about technology (which tended to involve machines, but not necessarily computers). Visitors will need support to help them understand why some topics, like stem cell therapy, are included as BMT. They will need to broaden their perceptions of what technology is, and what it can do for doctors and their patients. The concept of "biomedical technology" will be new to many younger visitors, although they may be familiar with some topics covered by the term.

Research and development of biomedical technologies. Respondents were more interested in BMT products, like images, machines, and cures, than in the processes used to develop them. Most respondents saw medical doctors as taking the lead in developing new technologies — doctors saw a need and found a way to fill it. Respondents often described doctors working alone on new technologies, except when they "got stuck" and needed help from an electronics expert, engineer, or scientist. When asked where new biomedical technologies might be developed, most respondents talked about places where doctors work, like hospitals and medical centers. Most respondents had little understanding of the interdisciplinary nature of BMT research and



development, or of the contribution that basic research makes to the process. Local GLSC visitors were interested in all connections to work done in Cleveland.

Local adult visitors often had a fairly broad understanding of Case Western Reserve University, usually because they had met and talked with Case graduates. Local adult visitors were often aware that the “Case” and “Western Reserve” sides of the university had different areas of focus, and many were aware of the medical school and/or University Hospital connection. Although visitors from neighboring states had sometimes heard of Case Western Reserve University, visitors from other parts of the United States or other countries were usually unfamiliar with Case. Most child respondents through middle-school age had never heard of Case Western Reserve University.

Cutting-edge vs. older technologies. Most respondents did not seem particularly bothered when we told them that the *Medical Technology* exhibits, and the technologies they showed, were ten years old. Respondents explained that they did not fault GLSC because technology changes so fast and new technologies are very expensive. Also, respondents expressed great interest in the older technologies. They wanted to know what doctors did before the newer technologies were developed and to see how far BMT had come. Respondents’ interest in older BMT was sometimes very personal: they wanted to show family members the technologies that had been used on them, and to see examples of technologies that had been used on older relatives.

Controversies and dilemmas in biomedical technology. For some visitors, certain BMT topics were seen as either controversial or personal ethical dilemmas. When we suggested that the new exhibition might include exhibits that either discussed or encouraged visitors to express themselves on these issues, some respondents were strongly in favor of this approach. Some even considered it an obligation for GLSC to take this route. Others said that, although these were not the kinds of exhibits they expected to find here at GLSC, they were open to the idea and might participate, depending on the issue. Those who were less favorable towards the idea of dialogue and debate expressed a number of concerns, including visitors who did not consider BMT to be controversial (because their minds were made up) and respondents who wanted only information and explanations, but not opinions. Respondents sometimes distrusted the opinions of other visitors, and thus did not want to see them on display. A few visitors said they did not want GLSC to raise these issues in front of their children. Finally, some respondents assumed there was outside pressure making the Science Center add discussion elements to the exhibits, sometimes expressing resentment at what they interpreted as religion infringing on science.

Personal connections and interests. Visitors to the *Medical Technology* exhibition displayed a range of personal connections to the objects and topics they encountered in this gallery. Some of the strongest connections were by visitors who had experienced—or thought they might someday experience—the medical procedures as a patient. We also talked with quite a few respondents who worked in health care, telling us (or their companions), “This is part of my job.” A few children described themselves as future medical professionals, although more frequently we talked with parents who said they wanted their children to be doctors when they grew up. Many children related to the specimens and devices because they were cool and gross. Also, many respondents were curious about aspects of BMT, asking such questions as: “What’s inside...?”



“How does it work?” “What does it mean?” Some visitors expressed special interest in a BMT topic because they had seen more advanced medical technologies on TV, or had read about them. Other visitors connected to the exhibits because they felt empathy for patients portrayed in the exhibit videos. Local visitors often expressed interest and pride when we told them that people had developed technologies right here in Cleveland.

Visitors expressed this broad range of personal connections even though many of the existing exhibits did not seem designed to elicit them. The team has many opportunities to design the new exhibits in ways that will strength visitors’ personal connections to BMT.

The importance of interactivity. It was clear that the interactives here differed from those in the most popular GLSC exhibitions. Because the range of physical engagements was limited, some exhibits presented too little (or too much) challenge, and there was little to encourage playful behavior. Children—especially older children—sometimes confided that the *Medical Technology* exhibits were not much fun compared to other parts of GLSC. Children often spent minimal time in *Medical Technology*, moving on to the *Sports Technology* exhibition or the *Science Phenomena* exhibits as soon as possible.

Proposed Major Topic Areas: Medical imaging. The five medical imaging exhibits in *Medical Technology* will be revised and included in the new exhibition. The existing exhibits were popular with visitors, and adult visitors were often familiar with the technologies because they had experienced, or anticipated experiencing the procedures. However, each of the current units presents unique development and design challenges, which are discussed, along with potential resolutions, in Appendix G: Summaries of Findings for Individual Exhibits.

Prosthetics, therapies, and cures. The Prosthetics and Functional Electrical Stimulation (FES) exhibits in *Medical Technology* will be revised and included in the new exhibition. Appendix G includes detailed evaluations of these elements. The fact that most GLSC respondents showed limited understanding of where stem cells occur in humans and of how they function within the body should be considered in the development of new exhibits. Respondents expressed surprise and interest when we told them that stem cells were found within adults (not just fetuses), and that they were used for bone marrow transplants. New exhibits on stem cells should present information about the types and uses of stem cells, as well as discussion of pros and cons related to stem cell therapies.

Genomics. *Genomics* is research based on an organism's entire genetic make-up (its genome) rather than specific genes. The genomics section of the new *Biomedical Technology* exhibition will be substantially revised from the existing genetics exhibits; several exhibits about non-medical applications of biotechnology will be dropped. The new exhibits will deal with topics such as DNA, the Human Genome Project, and personalized medicine. Personalized medicine uses a detailed knowledge of the human genome to test specific stretches of DNA to assess a patient's risk of disease, or reaction to potential treatments. Results showed that most adults and older children have a limited understanding of genetic terms and concepts, and younger children may have little or no understanding of the basics of genetics. Despite limited understanding of the abstract science of genetics, visitors may still attach a range of meanings to terms like “gene” and “DNA” based on popular cultural references. Most respondents had never heard of



“personalized medicine,” but when we asked them to guess its meaning, many adults were at least partially correct. GLSC visitors varied in their perceptions of potential ethical and moral controversies regarding genomics. As the genomics exhibits are developed and tested, the team should be sensitive to how visitors’ perceptions and understandings of these topics affect their engagements with the exhibits.

Infectious diseases. A new section of the *Biomedical Technology* exhibition will be devoted to BMT aspects of emerging infectious diseases. The report reviews some of the literature on people’s understanding and feelings about these topics. As the team develops and tests prototype exhibits for this section, they should take into consideration ways in which visitors’ incomplete or inaccurate knowledge about microbes and diseases may affect their responses to these new elements.

Models for thinking about the *Biomedical Technology* exhibition. The report discusses three models for thinking about the new exhibition. Deborah Perry’s model addresses the question, “*What makes exhibits fun?*” By using this model, the team can create exhibits that are engaging for visitors of all ages. Zahava Doering’s *Entrance Narrative* model starts with what’s inside the visitor. She claims that visitors enter exhibits with *entrance narratives*, which are internal story lines that (a) start with the fundamental way that individuals construe and contemplate the world; (b) include information about the given topic, organized according to that basic framework; and (c) are supported and verified by personal experiences, emotions, and memories. Finally, the Boston Museum of Science *Model for Technology Literacy in Museums* shows how museums can help their visitors consider the full range of technology-related issues. These models can help guide the team as they develop, design, and test the new BMT exhibits.

Recommendations. Although the grant proposal discusses a broad range of issues, we recommend that the team stay focused on the big idea for this exhibition: “Rapidly improving biomedical technologies give doctors new tools to improve personal and public health.” Every exhibit element must support visitors’ developing understanding of the project’s big idea. The team should also be aware of the emotional aspects of biomedical technology for many former (or current) patients, and find ways to make biomedical technologies more meaningful to visitors who have not had previous experience with them—especially members of the target audience (7th and 8th grade) and younger children. As exhibits are developed, the team should carefully consider the potential impacts of metaphors used in the exhibition (or brought by visitors). The team should use a range of carefully chosen media to help visitors understand basic concepts needed to make sense of BMT concepts and issues.

The report concludes with general recommendations for the development of the new *Biomedical Technology* exhibition. Specific recommendations for redeveloping existing exhibits are included with the individual exhibit evaluations in Appendix G.



INTRODUCTION

Background

Medical Technology is a 10-year-old, 2,750-square-foot exhibition at the Great Lakes Science Center (GLSC) dealing with a variety of issues related to medical and genetic technologies. With a grant from the National Institutes of Health, Science Education Partnership Award (SEPA), *Medical Technology* will be updated to create a new exhibition, *Biomedical Technologies*. The new exhibition will incorporate both updated version of the existing exhibits plus completely new elements. When completed, it will include approximately 10-15 stand-alone interactive exhibit units, including computer interactives, AV presentations, and working simulations of various biomedical equipment. Selinda Research Associates, Inc. (SRA) is the evaluator for the development of the new *Biomedical Technology* exhibition.

When this evaluation began in March, 2006, there were four main goals of the exhibition:

- Introduce visitors to biomedical technology (BMT), i.e. the interdisciplinary application of physics, engineering, math, and biology to medicine.
- Show how BMT improves and saves lives.
- Highlight Case Western Reserve University's (Case) cutting-edge research and application of BMT.
- Introduce participants to careers in BMT.

As of June, 2006, each major exhibit area in the new exhibition was planned to address a topic of biomedical technology:

- Medical Imaging.
- Genomics. (Genomics is research based on an organism's entire genetic make-up — its genome — rather than specific genes.)
- Prosthetics, Therapies, and Cures.
- Emerging Infectious Disease.

In addition, the team was developing a public programming area and a kiosk highlighting careers in BMT for the new exhibition. The target age range for this project has been set at 7th and 8th grades. However, the team intends to develop an exhibit that effectively achieves its goals for the full range of ages that visit GLSC.

SRA has conducted a front-end evaluation in order to help the *Biomedical Technology* exhibition team refine designs and achieve these goals. The research question for this study has been:

What can we learn about potential visitors' understandings of and connections with biomedical technology issues that will help the exhibition team develop an engaging and provocative exhibition?

Researchers for this project were lead researcher Eric D. Gyllenhaal, Senior Research Associate at Selinda Research Associates, and Katherine Ziff, Exhibit Developer at Great Lakes Science Center and lead developer for the *Biomedical Technology* project.



Description of the Existing *Medical Technology* Exhibition

At the time of this study, the exhibition included exhibit units dealing with the following topics, which roughly matched the topics for the new exhibition. The exhibit units marked with an asterisk (*) were to be updated or redeveloped for inclusion in the new *Biomedical Technology* exhibition:

- **Medical Imaging.** This topic included the following units: *An Inside Look* (Medical Imaging)*, *Magnetic Resonance Imaging* (MRI)*, *Seeing Around Corners* (Endoscopes)*, *Seeing with Sound* (Ultrasound)*, and *High-Powered Vision* (Microscopes)*.
- **Therapeutic Technologies.** This topic included the following units: *“Spare” Parts for People* (prosthetics)*, *Bringing Muscles to Life* (functional electrical stimulation, or FES)*, and *Keeping the Beat* (heart pumps).
- **Genetic Technologies.** This topic included a variety of technologies, some of which are medical and others that deal with agricultural and law enforcement applications of genetics. The units include: *Decoding Your Body* (DNA, Genes, and Gene Mapping)*, *Designer Genes* (genetic engineering), and *Genetic Crime Busters* (DNA Fingerprinting).
- **Health Careers Quest.** A separate computer kiosk*, set just outside the entrance to *Medical Technology*, introduced users to variety of health-related careers.

Photographs of the existing *Medical Technology* exhibition are included as Figures A1 to A5 in [Appendix A](#): Photos of the Existing *Medical Technology* Exhibition.

As part of the front-end evaluation, each of the units designated for updating/redevelopment was individually evaluated. These individual exhibit evaluations were originally produced as separate documents for attachment to the team’s Exhibit Design Reports on each exhibit unit. These reports have also been collected in to [Appendix G](#): Summaries of Findings for Individual Exhibits, which is included as a separate document. Because these evaluations incorporate thorough discussions of each exhibit’s components, we will not provide detailed descriptions here.



METHODS AND METHODOLOGIES

Methodology

In this study, we refer to methodology as the overarching paradigm or framework that guided the study. Methods refer to the specific data collection strategies or techniques. We used a naturalistic methodology to guide this study. Naturalistic methodology is often contrasted with positivistic or scientific methodology (Lincoln & Guba, 1985) and is based on a different set of assumptions (Rau, 1990). In accordance with naturalistic practices, the topics under investigation were explored from as many angles as possible, and the findings were triangulated to ensure their accuracy.

Methods

This evaluation was guided by a topical framework developed by GLSC and SRA ([Appendix B: Topical Framework](#)). The topical framework is a list of issues or topics we explored during the evaluation. It is phrased as a series of questions we endeavored to answer, using a range of techniques, outlined below.

There were four primary **methods** of data collection used during this study:

- Review of relevant literature,
- Unobtrusive observations of visitors in the *Medical Technology* exhibition,
- Participant observations of visitors in the *Medical Technology* exhibition,
- Depth interviews: face-to-face with visitors, and by phone with GLSC program staff.

Literature Review

To deepen our knowledge of potential visitors' understandings and feelings about topics related to biomedical technology (BMT), we reviewed the existing literature to assess what is already known about people's understanding of relevant science concepts and a range of other issues related to biotechnology. We searched the science education literature for published research about children's understanding of scientific and technological concepts, and the literature of public understanding of science for research of adults' understanding and attitudes about BMT-related topics. We also searched for evaluation and research studies about visitors' use and learning from exhibitions on these topics.

Observations

As part of our evaluation study, we unobtrusively observed visitors as they experienced the existing *Medical Technology* exhibits. During our observations, we looked for evidence of four types of visitor engagements: physical, intellectual, social, and emotional, as described below. These four types of engagements are not — and are not meant to be — mutually exclusive.



Physical engagements were all the physical things visitors did with the exhibits, such as standing, bending over, pushing a button, using a track ball, reading a label, looking closely at an object, watching a video, and so forth.

Intellectual engagements were all the ways in which visitors engaged cognitively and intellectually with the exhibits, including ways visitors thought about, processed, and made meaning of their experiences. Although we could judge some types of cognitive interactions through observations and overheard conversations, most of what we learned about intellectual engagements came from the interviews, described below.

Social engagements were the ways in which visitors engaged with each other within the context of the exhibits, including verbal exchanges and body language. We attended to the extent to which, and ways in which, visitors engaged socially with others in their groups.

Emotional engagements were all the ways that visitors engaged emotionally with the exhibits. We looked for indicators of relevant emotional engagements such as surprise, satisfaction, frustration, or confusion.

The data collection protocol for these observations is included as [Appendix C: Visitor Observation Protocol](#).

When possible, we purposively selected which groups to observe. With purposive sampling, each respondent group is selected based on the results of previous observations and interviews. As data were gathered and the preliminary analysis was conducted, new questions and areas of interest emerged. Respondents were selected purposively to illuminate different types of visitor experiences around those new questions and areas of interest. This ensured that we interviewed participants with a maximum range of experiences relating to the topics of interest.

Depth Interviews

After an observation, we usually approached the respondent group to request an interview. The decision to approach a group was based, once again, on our purposive sampling goals. Starting with the questions in the topical framework, we developed a depth interview protocol that focused first on what we had seen the respondents doing with the exhibits and then opened up to investigate a range of broader topics. A depth interview is an open-ended and relatively unstructured conversation between a researcher and one or more respondents. The interview protocol is included as [Appendix D: Visitor Interview Protocol](#). The protocol represented the starting point for our conversations with visitors. During each interview, we developed probing questions and new lines of inquiry based on the responses received from that respondent group.

To triangulate our findings from the literature review and visitor observations and interviews, we also conducted depth phone interviews with GLSC staff who had worked with visitors. Staff interviewees were recommended by the team based on their experience with visitors in the *Medical Technology* exhibit and demonstrated understanding of GLSC's educational approach. The interview protocol is included as [Appendix E: Staff Interview Protocol](#). These interviews



were recorded to aid in continuing analysis. As is the case with all depth interviews, we promised these respondents that we would treat their interviews as confidential and not cite their comments with attribution within the final report.

Participant Observations

In addition to the unobtrusive observations, we conducted participant observations. With visitor permission, we joined an individual or group as they interacted with an exhibit unit, and asked them what they are doing, thinking about, and experiencing. Participant observations often yielded an abundance of information that is not possible with the un-cued unobtrusive observations and depth interviews described above. We were very careful to make sure the data collector did not influence the visitor experience.

After each observation and interview at the exhibit, we went back to an office area to write a debrief describing our findings for that individual or group.

Respondents

As described earlier, respondents for the observations and interviews with GLSC visitors were purposively selected casual visitors to the existing *Medical Technology* exhibition. Purposive sampling is a standard technique used in naturalistic inquiry to ensure a broad range of visitor perspectives. Brief, tabulated descriptions of these respondents are included in [Appendix F: Descriptions of the Respondents](#).

When conducting research, there is always tension between the desire to collect small amounts of information from a large number of people and the desire to collect large amounts of information from a small number of people. For this study, we were interested in helping the project team develop a deeper understanding of how visitors think and feel about topics related to BMT. Therefore, we collected a relatively small sample of observations and interviews about what visitors were thinking about these topics. Counting observations and interviews conducted by both SRA and GLSC staff, 90 individuals in 33 groups were formally observed, and 100 individuals in 39 groups participated in interviews. (53 individual visitors in 23 groups were both observed and interviewed.)

Respondents for the interviews with GLSC included two members of the programming staff. These respondents were selected by referral from the project team. The names and job titles of these respondents are listed in [Appendix F](#).

Analysis

Data analysis for this study was an on-going process using a modified inductive constant comparison approach (Lincoln & Guba, 1985). This method takes each unit of data and systematically compares it to all previous units of data. For instance, data analysis for the visitor observations and interviews took place at three junctures. The first was during the actual interview. During the interview, preliminary understandings were developed and tested out with respondents. After an interview or series of observations, the researcher typed a formal debrief at a computer. The debrief summarized the data collection session, recorded the researcher's



interpretation of the session, and compared it to previously collected observation and interview data. At the same time, the researcher also developed questions to be explored in subsequent data collection sessions, including any special areas of interest. Finally, the third interval of data analysis took place during the planning and writing of this report, as the researchers revisited the debriefs, discussed the findings and preliminary conclusions, compared them with data collected from other parts of the study (e.g., the literature review and expert interviews), and wrote and revised the report.

Because of the iterative nature of the analysis, readers will not find a one-to-one correspondence between a piece of data and a conclusion or recommendation. Rather, the findings discussed in this report have been triangulated by comparing and synthesizing data gathered from a variety of sources.

Knowledge Hierarchies

The development of knowledge hierarchies has been an important tool for analyzing and presenting the results of this study. A knowledge hierarchy technique (Perry, 1989, 1993a) can describe the ways in which visitors think about and potentially understand the sorts of topics included in this study. A knowledge hierarchy presents a range of visitor understandings about a certain topic, based on the assumptions that (a) there is an internal knowledge structure inherent in an exhibit topic, and (b) this hierarchy is located at the intersection of the exhibit developer's and the visitor's organization and understanding of the topic. Thus, a knowledge hierarchy is simply a description of the range of visitors' pre-existing understandings about a topic within the context of the planned exhibit. It usually describes six or seven levels of understanding, covering a full range of how visitors think about a topic, usually by increasing levels of sophistication. The hierarchy represents, in manageable form, virtually all visitors' understandings about that aspect of the topic. As such, knowledge hierarchies are a way of helping science centers address the needs and interests of a greater proportion of their audiences.

The structure of knowledge hierarchies tends to follow a certain pattern (adapted from Perry, Garibay, & Gyllenhaal, 1998). This example has six levels (labeled as Levels Zero through Five), although five- and seven-level hierarchies are sometimes more appropriate.

Level Zero: **"Don't know and don't care."** Visitors at this level often have not thought much about the topic and have not developed any particular interest in it. They sometimes can be motivated to become curious about the topic, but they have not thought about it much on their own.

Level One: **"Don't know, but I was wondering."** These visitors have formed questions about the topic in their minds, but they have not yet developed answers to their questions.

Level Two: **Incomplete and/or incorrect understanding.** These visitors are interested enough in the topic that they have formed some understanding of it, but their ideas are unsophisticated, largely incomplete, and sometimes incorrect in important ways.



Level Three: Basic understanding. These visitors have a fairly accurate *basic* understanding of the topic, although they may be fuzzy or sometimes incorrect on the details.

Level Four: More sophisticated. These visitors have a more sophisticated and accurate understanding of the topic and may articulate detailed information about one or more aspects of it. These visitors sometimes have a particularly strong interest, background in college-level courses, or direct experience working with the subject.

Level Five: Very sophisticated. These visitors have a very sophisticated understanding of the topic, and include people who have studied the topic extensively or have chosen a career related to the topic.

Although knowledge hierarchies are often used to *describe* visitors' current understanding of a topic within the context of an exhibit's topic, the knowledge hierarchies presented in this report also fulfill several other functions. They also try to help the exhibit team *structure the goals and messages* for a given topic according to visitors' interests and existing knowledge. This is particularly important when most visitors are at Levels Zero, One, or Two for a given topic, as was often the case in this study. Given the team's often ambitious goals, what basic, Level Three, understanding should an exhibit aim for? Which messages should be considered secondary, because they are likely to be beyond the interests and knowledge of all but the most sophisticated visitors? Also, many of the hierarchies include *recommendations* about the sorts of support will visitors need to move up the hierarchy, such as basic explanations of essential background knowledge and opportunities to re-examine alternative understandings. Finally, the hierarchies often provide *specific examples* of what a Level Three, Four, and Five understanding might look like, as well as presenting some examples of alternative understandings at Level 2.

Knowledge hierarchies are a way of helping science centers address the needs and interests of a greater proportion of their multiple audiences, and therefore have been an important tool for analyzing and presenting the results of this study.

Limitations

Due to limited resources, this study was necessarily limited in scope. For example, when conducting an evaluation study using naturalistic methodologies, it is standard practice to continue collecting data until a *state of redundancy* is reached. Redundancy is the point at which no new information is gleaned, despite repeated attempts to elicit additional findings. We seem to have achieved redundancy for many of the issues listed in the topical framework. However, we received a more limited range of responses in some areas of the study. For instance, we were unable to talk with visitors in depth about a variety of issues related to genomics and infectious diseases.

Where appropriate in the report, we identify issues we were unable to resolve satisfactorily in the field. Because we were not able to completely triangulate these findings through interviews with



GLSC visitors, they should be interpreted cautiously and, if possible, investigated in greater depth with visitors during formative evaluation.

During periods of relatively light visitation, we selected the next available visitor group to the exhibition in order to maximize our contact hours. Because of this, we interviewed fewer children in the target age range (grades 7 and 8) than we had intended.



RESULTS

The results of our studies of visitors in the *Medical Technology* exhibition are presented in two ways. General findings are presented here, and findings specific to the individual exhibits have been collected into [Appendix G](#), which is included as a separate document.

The Meaning of Biomedical Technology

When we asked visitors what the term “biomedical technology” meant to them, adult respondents often made fairly accurate guesses, even though many of them were unfamiliar with the term “biomedical.” The term “medical” had clear meanings to adults, and made them think about “cures” that used technology in some ways. When asked about alternative terms, “medical technology” was better understood by many respondents; however some adults said “medical technology” didn’t seem as appealing — it was too bland. Respondents told us that “medicine” used alone wasn’t enough, because it implied “pills and all that.”

There were many indications that children through middle-school age had difficulty making sense of the term, “biomedical technology.” The term was long and unfamiliar, and the prefix, “bio,” led some children onto the wrong track (suggesting other “bio” words, like “biomes”).

When we asked visitors what topics they would expect to see in an exhibit about “biomedical technology,” certain topics were common to all of our respondents because they included both “cures” (i.e., the medical part) and something that fit their preconceptions about technology (which tended to involve machines or computers). The most widely recognized BMT topics included heart disease and paralysis. Visitors listed cancer as a BMT topic when they remembered that radiology could be used as a treatment. Infections diseases were regarded as BMT topics when they were “new” diseases for which doctors were actively looking for cures; for example, our respondents tended to see avian flu and bio-terrorism as a BMT topics, but not malaria. Our respondents were divided as to whether gene therapy should be included as BMT.

National surveys indicate that when the term “technology” is used alone the American public often thinks of computers and other forms of “high technology” (Rose & Dugger, 2002). However, our respondents rarely mentioned computers during our initial discussions of the meaning of “biomedical technology.” Rather, they talked about biotechnology “machines” in a much broader sense. When we raised the issue of the computers inside those machines, adult respondents said they were not surprised, because “computers are everywhere these days.” On the other hand, most child respondents (10 years and under) needed guidance to think of the biomedical applications of computers. Their initial thoughts about what computers can do included games and educational applications, like searching the web and “typing.” However, once we reminded them about robot brains and computer graphics, these young respondents were quite open to finding computers in, for instance, the FES and medical imaging exhibits.



Overall, it was clear that adult visitors will need support to help them understand why some topics, like gene therapy and “old” diseases, are included as BMT. They will need to broaden their perceptions about what technology is, and what it can do for doctors and their patients. Younger visitors will often be new to the whole concept of “biomedical technology,” although they may be somewhat familiar with some of the topics covered by the term.

Research and Development of New Biomedical Technologies

When given a range of choices about different aspects of BMT that could be included in the new exhibit, learning about the “who, where, and how” of developing new biotechnologies was low on visitors’ lists. Respondents were much more interested in BMT products, like images, machines, and cures, than in the processes used to develop them.

Who Develops New Biomedical Technologies?

When we asked respondents *who* they thought might develop new biomedical technologies, most thought medical doctors took the lead by seeing a need and finding a way to fill it. Some respondents seemed to think that doctors worked alone, except perhaps when they “got stuck” and needed help from an electronics expert, engineer, or scientist.

We talked with visitors about a variety of terms used for professionals who work in BMT fields:

- **Clinician**—Medical doctors are referred to as clinicians if they treat patients. However, many visitors were confused by this term, often because they had experience with small medical clinics as places to receive medical treatments. Some respondents had a fairly broad understanding of the term as any medical professional who helps cure disease, or helps with recovery. Other respondents said they thought of clinicians as people who work for doctors and scientists, such as assistants in a lab or clinic or lower-level employees (“like the girl who takes your coat”).
- **Researcher**—Many respondents had very broad understandings of this term as one that applies to many fields, such as science, engineering, and social science. Others thought more specifically of scientists conducting experiments. Children often talked about research projects they had done at school, and some considered themselves to be researchers because of that. For a few respondents, the term “researcher” had negative connotations because it brought to mind research on animals and “other unpleasant things you don’t want to think about.”
- **Investigator**— Most respondents said they associated the term “investigator” with crime, detectives, the TV show *CSI*, and police work. However, a few respondents said they thought researcher and investigator could be the same thing, including students who had taken inquiry-based science courses. A few respondents said they considered investigation to be part of the scientific process; “they have to investigate before they do the research.” Some respondents advised us that “investigator” sounded more interesting than “researcher” and thus would be a better term to use in the exhibit.



- **Scientist**—Although most respondents said that scientists do research, scientists also were perceived as technology experts who could be called in to solve problems that doctors encounter when developing new technologies. This was not surprising because many Americans fail to differentiate between science and technology (Rose & Dugger, 2002). Only one respondent brought up the idea of basic scientific research as the starting point for a new technology (in relation to the discovery of magnetism as a contribution to development of the MRI).
- **MD**— Respondents recognized this as an abbreviation of “medical doctor.” Many respondents agreed that MDs could do research as part of their work, but some only thought of MDs’ research as a step in developing treatments for individuals rather than as original scientific research. These respondents said things like, “They need to do research to make a diagnosis,” or “When they get a new problem with a patient and have to research how to solve it.”
- **PhD**—Adult respondents, especially the college-educated adults, said PhDs seemed more likely to do research than MDs.

Visitors have preconceptions about any term for the professionals involved in developing new biomedical technologies. Regardless of which terms are used, the team should define, qualify, and illustrate their intended meanings using a variety of media, including labels, photos, and multimedia presentations.

Where Are New Biomedical Technologies Developed?

When we asked respondents *where* new biomedical technologies might be developed, most talked about places where doctors work, like hospitals and medical centers. A few respondents also mentioned “research centers,” “big companies,” and universities. The Cleveland Clinic was mentioned several times. Once we mentioned that Cleveland was a center for the development of new biomedical technologies, it was clear that local visitors were interested in the “Cleveland connection” in all its forms. Several local visitors expressed pride at the Cleveland connection, and some visitors from other locations expressed pride in BMT organizations that were located in their home towns.

When we talked with respondents about Case Western Reserve University (Case), local adult visitors often had a fairly broad understanding of this institution. Some said they had heard of the “engineering stereotype” for this school. However, they said they didn’t believe it, or they used to believe it and had revised their opinions as they met and talked with people who had gone there. Local adult visitors were often aware that the “Case” and “Western Reserve” sides of the university had different foci, and many were aware of the medical school and/or University Hospital connection. Interestingly, few visitors mentioned current issues in the newspapers during our study, such as the University’s planned name change and financial difficulties. Although some visitors from neighboring states had heard of Case Western Reserve University, most visitors from other parts of the United States or other countries were unfamiliar with it. Most children through middle school age had never heard of Case Western Reserve University.



How Are New Biomedical Technologies Developed?

When respondents were asked how new biomedical technologies might be developed, most thought the process began with a need—a medical problem that needed to be solved. However, it was clear that most respondents had little understanding of the interdisciplinary nature of the development process, or of the contribution that basic research makes to the process.

Knowledge hierarchy about the research and development of new biomedical technologies

As we discussed in the [Introduction](#), a knowledge hierarchy presents a range of visitor understandings about a certain topic. The following knowledge hierarchy summarizes visitors' understandings about the development of new biomedical technologies. It includes six levels of understanding, characterizing the range of ways that our respondents were thinking about research and development of new technologies by increasing levels of sophistication.

Level Zero: “I don’t know, and I don’t care.” These visitors had not thought about how new biomedical technologies were developed. For the most part, they were not interested in learning more about BMT research and development, although they were often interested in other aspects of BMT. It’s important to note that when we talked with Level Zero visitors about this topic, they rarely became interested enough to move to Level One.

Level One: “I was wondering....” Although visitors were willing to hazard guesses to answer our questions (e.g., see Level Two), few developed their own questions about this topic. The few visitors who had developed their own questions about BMT research and development had seen or heard about new biomedical technologies on television or other media.

Level Two: Incomplete or incorrect understandings. As discussed earlier, when we asked them to speculate how new biomedical technologies were developed many respondents expressed incomplete understandings of BMT research and development. They were not actually wrong in what they knew, or guessed, about the process. However, they showed little understanding of the “who,” “where,” and “how” of biomedical technology development. For instance, most respondents assumed medical doctors take the lead in developing ideas, basically working alone except when they “got stuck” and needed help from a specialist in science or electronics. Also, many visitors guessed that hospitals and medical centers were centers for BMT development, but few mentioned universities. Finally, most respondents had little understanding of the interdisciplinary nature of BMT, the role of computers in cutting-edge BMT, or the contribution that basic research makes to the process.

Level Three: Basic understanding, such as “new biomedical technologies are developed right here in Cleveland at places like Case Western Reserve University.” We talked with several respondents who knew that biomedical technologies were developed in Cleveland, although they more often thought about Cleveland Clinic than Case. Because Level Two visitors’ understandings are incomplete in so many dimensions, it may be a challenge to prioritize where the exhibition should focus



in increasing visitors' understanding to the process. Because local visitors expressed pride in connections to Cleveland, emphasizing this may be used to motivate some Level 2 visitors to move up a step or two in understanding.

Level Four: **More sophisticated understanding, such as “new biomedical technologies are developed by teams of medical doctors, engineers, therapists, and computer scientists.”** None of our respondents had reached this level or Level Five prior to our interview. We suggest that the team should be specific about the disciplines involved in the development process, rather than using a more general term, like “interdisciplinary.”

Level Five: **Very sophisticated understanding, such as, “new biomedical technologies are developed through a complex, multi-stage process.”** We suggest that details about the complexity of the research and development process will be of interest mainly to medical and science professionals, and perhaps to those who are directly affected by a particular medical problem.

By starting with this hierarchy, the team can think about ways to reshape visitors' understandings about the development of new biomedical technologies.

Biomedical Technology Careers

We talked with visitors about careers related to biomedical technology at both the *Health Careers Quest* computer kiosk and elsewhere in the *Medical Technology* exhibition. We found that children and adults related to this topic in very different ways.

Most children we talked with—including younger children and teens—expressed little interest in learning more about careers as they explored the exhibits. The exceptions included children who were exploring the exhibits with their medical-professional parents and children who had already developed interests and ambitions in this field. For instance, we met a few children who, based on their studies in school, expressed interest in a career in scientific research or medicine. Although their interest seemed strongly motivated, these children often showed a limited understanding of the nature of these careers (e.g., the child who wanted to work as a “gene splicer”). However, we spoke with relatively few children who expressed these strong interests. More typically, teens and younger children told us they were looking for fun, interactive experiences at GLSC, which to them did not include learning about potential careers. We should also note that some children already considered themselves to be headed towards non-scientific futures and expressed negative reactions to any career related to science.

Adult visitors' interest in biomedical technology careers took several forms. Parents often expressed interest and even enthusiasm about exhibits that could inform and interest their children about medical careers. Many parents said they hoped their children would become medical doctors. Adults who were medical professionals related to biomedical technology careers in at least two ways. Those who were touring the exhibits with their children, parents, or friends often took the opportunity to tell their companions something about their own work in the medical field. Those who were visiting alone sometimes explored the *Health Careers Quest*



computers, often because they wanted to see how well, and to what extent, their profession was depicted by the program. Finally, educators often explored the *Health Careers Quest* computers in search of resources and ideas for developing career presentations for their students.

It's important to note that most visitors' thinking about biomedical technology careers was severely limited because they failed to recognize the true interdisciplinary nature of biomedical technology. For instance, very few visitors had given much thought to the roles that engineers and computer scientists play in biomedical technology.

Finally, a number of parents and educators shared with us their thoughts and experiences on effective ways to interest children in biomedical technology careers. The consensus was that the most effective approaches brought real, live professionals in contact with children in classrooms or at career fairs. Our respondents also recommended that these professionals use interactive presentations to attract and hold the children's interest.

For a more detailed discussion of our findings and recommendations about the *Health Careers Quest* computer kiosk, see Appendix G.

Cutting-edge vs. Older Technologies

Most respondents did not seem particularly bothered when we told them that the *Medical Technology* exhibits, and the technologies they showed, were ten years old. As respondents explained why they were not bothered by the lack of the most recent technologies, they revealed aspects of their own beliefs about technology and the Science Center:

- **Technology changes so fast that only specialists can keep up.** To see the latest advances, you have to go to medical conferences, not science centers or museums.
- **Keeping up with new technologies is very expensive.** What you see on display was donated, and medical people probably only donate things that are older and no longer useful.
- **Older technologies are interesting.** That's what some respondents expected and wanted to see. As some said, "This is a museum, after all," where you expect to see older things.
- **The science center deals with scientific principles,** and principles don't change as fast. A few visitors explained that GLSC was about science to them, not technology.

Respondents' interest in older examples of medical technology also reveals aspects of their beliefs about, and relationships to, technology. For example, they wanted to know what doctors did before this technology was developed, and to see the first example developed, as well as later versions. They wanted to show family members the technologies that had been used on them, and examples of technologies that had been used on older relatives. In other words, their interest was in some ways very personal, and in other ways related to their interest in seeing examples of medical progress.



Some respondents expressed great interest in seeing more up-to-date technologies—especially if they anticipated someday needing those technologies. Also, a few respondents said they felt it was GLSC’s duty to show only the latest versions of all the technologies. These respondents seemed to have a different view of what a science (and technology) center was all about.

We continue this discussion below, in the section entitled [Visitors’ Entrance Narratives](#).

Controversies and Dilemmas

As we talked with visitors about a range of biomedical technologies, it became clear that for some visitors certain topics were either seen as broadly controversial or as personal ethical dilemmas. When we suggested to visitors that the new exhibition might include exhibits that either discussed or encouraged visitors to express themselves on these issues, we received a broad range of reactions.

Some respondents were strongly in favor of this approach and thought they would probably participate in any opportunities for dialogue, often because they had strong opinions and had personal stories that they wanted to tell. A few saw it as an obligation for GLSC. If the exhibits present a topic like stem cells, then “you should get to express your opinion.” Other respondents said that is not the kind of exhibit they expected to find at GLSC, but they were open to the idea and might participate, depending on the issue.

Although the majority of visitors we spoke with seemed open to the idea that GLSC would solicit visitor comments on controversial issues, respondents expressed a wide variety of concerns about this sort of exhibit, including the following:

- **There are no ethical issues here.** Some respondents’ initial reactions were that, as far as they were concerned, there were no ethical issues with whatever we were talking about at the time. Their minds were made up, and they were not open to any further debate. However, some later warmed to the idea of expressing their made-up minds. Other respondents said they trusted the doctors on these issues and would leave the decisions up to them. (This may reflect the view that the issues are too complex for anyone but the experts.)
- **Provide information, not opinions.** Some respondents said the Science Center should provide information, not opinions. For instance, some respondents said the Science Center should just explain the science and technology behind the supposed controversy, and visitors who did not want to read the information could ignore the exhibits and move on.
- **Think and talk about it later.** Some respondents said they wanted to read the information here at the Science Center and then go home to think about it and perhaps discuss it with family and friends.



- **Let others read the information.** Some respondents wanted other visitors to read the information, presumably because having better information would cause the other visitors to change their opinions on the topic. As one visitor put it, “The exhibit should give people the information they need to develop an informed opinion,” with the implication that those who had a different opinion were uninformed.
- **Other visitors’ opinions may not be worth much.** Related to the previous point, some respondents claimed that other visitors’ opinions about stem cells, for example, would be knee-jerk, uneducated, or based on religion and politics and not science. The opposition was seen as standing in the way of scientific progress. On the other side of the issue, respondents said that other people’s opinions would be too narrowly focused on the benefits without also considering the costs.
- **Not in front of the children.** Some said that parents should be free to discuss these issues with their children at home. Families should not be forced to confront them for the first time in a public science center.

Interestingly, some respondents assumed that outside groups were pressuring the Science Center to add discussion elements to the exhibits, raising religious and political issues these respondents viewed as infringing on science.

We discussed a variety of possible exhibit formats with visitors and observed a wide range of reactions. Possibilities included: (1) posting a written comment (a few were enthusiastic while others said they would never do it), (2) talking about it with family and friends (some do this on their own anyway), (3) “voting” on a range of written statements (concern about young button-pushers skewing results), and (4) sitting down for a moderated discussion (some were concerned about the amount of time it would require).

Personal Connections and Interests

Visitors to the *Medical Technology* exhibition displayed a range of personal connections to the objects and topics they encountered in this gallery. This section lists and describes the different types of personal connections we identified during this study.

Medical patients

Some of the strongest connections to the exhibits were by visitors who had experienced—or thought they might someday experience—the medical procedures in the exhibition as a patient. These respondents took this opportunity to think and talk about (or anticipate) their experience and to try to learn more about what had happened/will happen. Some, but not all, expressed an interest in finding out about what had happened to the technology since their procedure. Those who were anticipating someday experiencing a colonoscopy were also interested in any advances on the horizon.

The family and friends of former medical patients also had their interest piqued in that particular aspect of the exhibit. If the former patient was with them, then their friends and relatives often



heard about what had happened from an insider's perspective. If the former patent was elsewhere, these respondents said they were still thinking about them and trying to find out more about what they had been through.

Current health care professionals

We talked with quite a few respondents who worked in health care as everything from MDs to pharmacists to medical billing staff. These visitors told us, "This is part of my job," or "This is something I encountered while doing my job, and now I want to learn more about it." Some medical doctors pointed out to us that even they were learning new things about medical technologies that they had rarely encountered in their area of specialty. The family and friends of these health care professionals often received first-person interpretation about the devices and images on display.

Future health care professionals

When we raised the subject with children, a few said things like, "This is what I want to be when I grow up," although their understanding of the field may have been a bit naïve (like the child who said he wanted to be a "gene splicer" when he grew up). More frequently, we talked with parents who said they wanted their children to be doctors when they grew up.

Cool and gross

The specimens and devices were cool (and gross) things to look at and fun things to do. To these visitors, many of whom were children, it was "Here's another science center place to play and explore." With many of the interactives, the hook seemed to be meeting the challenge or learning the skill. "It's here, and I want to get good at it." With the prosthetics and medical specimens, the hook was that they were "gross," but in a cool kind of way. This sort of connection may have been the starting point for more meaningful engagement—especially if a parent intervened—but many of these visitors were not yet intellectually engaged with the content.

Curiosity

Many respondents were curious about aspects of BMT, asking such questions as "What's inside...?" "How does it work?" "What does it mean?" These sorts of questions were asked most often about four major subject areas:

- **Human body.** Children especially were curious about what was inside the human body, and many families related to the exhibits by trying to answer their questions. These visitors looked at the medical images and the prosthetics to learn and teach about the body, rather than the technology.
- **Medical images.** These visitors were more curious about how the medical images were interpreted than about how they were made. Some of these visitors—often mothers—had had ultrasounds while pregnant, but had been left a bit confused by the process. They told us that everything had happened so fast that they never really learned how to make sense of the images. Visitor interest in interpreting images and what is inside the body intersected at the bank of Medical Imaging monitors, where many visitors tried to relate what they saw on the screens to their knowledge of human anatomy.



- **Mechanical and electronic technologies.** These visitors were curious about what was inside the technological devices, and how the insides worked. Adult visitors—often male—looked inside the MRI, for instance, trying to find the strong. Many children’s eyes lit up when we suggested that the new exhibit could take off the cover so they could look inside the biotechnology machines.
- **Science.** We also heard from visitors who were curious about the science, often because it was presented in an engaging way. For instance, some visitors, who had learned something about DNA in school, said they appreciated the chance to see the increasingly large images on the DNA Zoom. Others were engaged by looking through the microscope. However, visitors were less engaged by science when it was presented only through text and diagrams, as it was on the main labels for the MRI and Endoscope exhibits.

New technologies

Some visitors had seen TV shows or read about more advanced medical technologies, sometimes beyond what was shown in the current exhibit. They wanted to learn more about these new technologies.

Empathy

These visitors felt empathy for the patients portrayed in the exhibits. This connection was seen almost exclusively at the FES exhibit.

Local pride

When we brought up the local connection, local visitors expressed interest and pride that people had developed or made the technologies right here in Cleveland. (Note: This wasn’t emphasized in the current exhibits.) Other visitors, on their own, recognized connections to their own hometowns or universities, and expressed their pride in that.

Ethical issues

These visitors were concerned about the ethical and moral issues related to medical technologies. This was not common as an initial connection for most of our respondents, but it did emerge during our conversations with some visitors.

Visitors expressed this broad range of personal connections even though many of the existing exhibits did not seem designed to elicit them. The team has many opportunities to design the new exhibits in ways that will strengthen visitors’ personal connections to BMT.

The Importance of Interactivity

As we watched visitors and talked with GLSC staff, it became clear that the interactives in the existing *Medical Technology* exhibition differed from those in the most popular exhibit areas. The differences included:

- **The range of physical engagements was limited.** The *Medical Technology* interactives tended to be push button and behind glass, and they usually presented visitors with a limited range of interactions with the exhibit.



- **Although a few exhibits challenged visitors, these challenges sometimes were difficult to meet.** For instance, at the “*Spare*” *Parts for People* computers, there were few obvious clues about where to place the prosthetics on the body outline, and it was difficult for visitors to achieve a satisfactory gait by pushing buttons at the FES exhibit.
- **There was little to encourage playful behavior.** Although we saw some brief episodes of role-playing, these rarely lasted more than a few seconds. More typically, visitors’ playful interactions with the *Medical Technology* exhibits were limited to brief intervals of unfocused exploratory play.

Children—especially older children—sometimes confided that the *Medical Technology* exhibits were not much fun compared to other parts of the museum. Of course, children more typically voted with their feet, moving on to the wheelchairs, *Sports Technology* exhibits, or the *Science Phenomena* exhibits as quickly as possible.

We will revisit the issues of play and interactivity in the Discussion subsection entitled, [Making Exhibits Fun](#).

The Big Idea

The big idea for the new *Biomedical Technology* exhibition is, “Rapidly improving biomedical technologies give doctors new tools to improve personal and public health.” As explained in Serrell (1996), a “big idea provides an unambiguous focus for the exhibit team throughout the exhibit development process by clearly stating in one noncompound sentence the scope and purpose of the exhibition” (p. 2).

Knowledge hierarchy about the existing *Medical Technology* exhibition

In this subsection, we present a knowledge hierarchy describing the range of visitors’ understandings about the themes of the existing *Medical Technology* exhibition. By analyzing this hierarchy, we can better understand some of the challenges the team will face in presenting the new big idea to GLSC visitors.

Level Zero: “**I don’t know, and I don’t care.**” These visitors didn’t see anything they wanted to do in *Medical Technology*—or they saw something they wanted to do more in *Sports Technology*—so they never developed an opinion about the exhibition’s topic.

Level One: “**I was wondering...**”. These visitors saw the medical devices and other exhibits and started wondering what they were all about. They had a chance to develop some questions about the exhibition’s topic, but they hadn’t developed answers yet (perhaps because they were following a child who was at Level Zero).

Level Two: **Incomplete and/or incorrect understanding, such as “the exhibits are about the human body and human health.”** To some visitors, the exhibits were about what’s inside the human body, how the body and its parts work, and how you can



get healthy. For instance, families often used the exhibits to explore and learn more about the human body as a group, with parents helping their younger children make sense of what they saw.

Level Three: Basic understanding, such as “the exhibits are about the things that doctors use to look inside us and to fix the problems they find.” These visitors saw the exhibits as device-oriented, rather than body- or health-oriented. They were exploring things that doctors use with patients—including some that may have been used on them. They wanted to see the devices, try some of them out, and share what they knew about them with their family and friends.

Level Four: More sophisticated understanding, such as “the exhibits are about how medical technology works and what it’s used for.” This level included visitors who dug deeper, trying out the devices more than once and reading labels to find out more about the technology. It included visitors who focused on things like learning how to interpret medical images, and visitors who used the exhibits to teach these deeper concepts to others in their group.

Level Five: Very sophisticated understanding, such as “it’s about the science behind the technology.” A few visitors dug even deeper, using the labels and interactives to explore and learn more about the science of genetics, microscopes, or MRIs.

Proposed Exhibit Topics

During the last few months of exhibition planning, the team has developed and refined the list of topic areas to be included in the new *Biomedical Technology* exhibition. As this is written, the team is planning to devote sections of the exhibition to applications of biomedical technology in four major areas: Medical Imaging; Genomics; Prosthetics, Therapies and Cures; and Infectious Diseases. In this section, each of these topic areas is discussed separately. We summarize what we learned about how visitors think and feel about biomedical technology within each topic area, based on our conversations with GLSC visitors and on reviews of the literature. We also summarize these findings in a series of knowledge hierarchies, which portray how visitors are likely to relate to the goals and messages being developed for different sections of the exhibition.

Medical Imaging

Overall, most visitors expressed interest in the existing medical imaging exhibits and became engaged with the more interactive aspects of the exhibits. Younger visitors and their parents often used the images to initiate teaching-learning engagements and discussions about human anatomy, especially at the Medical Imaging monitors. Many adult visitors discussed their personal experiences with MRIs, endoscopes, and ultrasounds with their companions. These personal experiences also provided parents with a starting point for teaching their children about the images and the devices that produced them. Each of the existing units presented issues that will need to be resolved as the units are redeveloped for the new *Biomedical Technology* exhibition. In particular, most exhibits need to find ways to focus visitors’ attention on the medical applications of these devices. However, with appropriate improvements, these units



should become engaging components providing strong support for the big idea of the new exhibition.

Our detailed findings about the existing medical imaging exhibits are discussed in the individual exhibit evaluations in Appendix G (including the Medical Imaging monitors, MRI, Endoscope, and Ultrasound). In the following subsection, we present a general knowledge hierarchy for visitors' understandings of medical imaging.

Knowledge hierarchy about medical imaging

Level Zero: **“I don’t know, and I don’t care.”** We talked with very few visitors who were uninterested in the medical images displayed in the exhibits.

Level One: **“I was wondering.”** These visitors saw the images or medical imaging devices and started wondering what they were all about. They had a chance to develop some questions about the exhibition’s topic, but they hadn’t developed answers yet.

Level Two: **Incomplete and/or inaccurate understanding, such as “the medical images provide views inside the human body.”** Most respondents at this level understood that the images showed views within the human body and focused on understanding what aspects of internal anatomy they were seeing. They concentrated on understanding the internal anatomy visible in the images rather on the technology that made the images. The existing exhibits provided relatively little interpretation of individual images, so visitors sometimes misinterpreted what they saw because their existing knowledge, and the knowledge of others in their groups, was incomplete or incorrect.

Level Three: **Basic understanding, such as “medical imaging devices allow doctors to visualize, non-invasively and without surgery, the hidden information they need to diagnose and treat diseases and injuries.”** This Level-Three understanding combines two of the learning goals for medical imaging, implying that a basic understanding involves shifting visitors’ focus to include three things that many of them did not give much thought to in the current exhibit: (a) the devices that produce the images; (b) the ultimate goal of the images (to diagnose diseases and injuries); and (c) the advantage of using these imaging devices (they let doctors see inside without doing surgery). The *Endoscope* exhibit seemed to be most the effective of the current exhibits at focusing visitors’ understanding in these ways, perhaps because visitors were actually able to manipulate a relatively familiar device to produce images. The Medical Imaging monitors seemed less least effective at focusing visitors’ ...

Level Four: **More sophisticated understanding, such as “advances in medical imaging devices produce more detailed images for diagnosis and treatment, with less discomfort and less radiation exposure for the patient.”** By stating the Level Four understanding in this way, we emphasize that the next step beyond a basic



understanding should focus on the advances taking place in medical imaging. This seems consistent with the main message or big idea of the exhibition, which emphasizes “rapidly advancing” technologies and “new tools.”

Level Five: Very sophisticated understanding, such as “advanced medical imaging devices would be impossible without modern computers.” This Level Five understanding is one of the learning goals of this section of the exhibition. We state it as a Level Five understanding because this goal seems pretty far from what will be important to most visitors about this section of the exhibition, and because it seems to provide only secondary support for the main message or big idea of the exhibition. However, this message may also serve as a hook for more technologically inclined visitors.

Genomics

Genomics is research based on an organism's entire genetic make-up (its genome) rather than specific genes. Although we did not have time to interview GLSC visitors about their general knowledge and feelings about genetics, there is a large literature base on this topic. A selected bibliography of research and evaluation resources on this topic is included as [Appendix H: Bibliography of Research on Public Understanding of and Attitudes about, Genetics and Related Topics](#). It includes research from a number of academic fields, including science education (e.g., research by Jenny Lewis, John Leach, and Colin Wood-Robinson), and the public understanding of science (e.g., research by Celeste Condit, Rosaleen Love, and Miltos Liakopoulos).

The goals of the *Biomedical Technology* project do not specifically include increasing visitors' overall knowledge about genetics. However, specific exhibits will need to explain genetics concepts so that visitors can understand what the BMT procedures are designed to accomplish. Visitors' preconceptions and prejudices about genetics-related topics will doubtless affect their understanding of and responses to a variety of exhibit elements. Genetics-related exhibits in the new *Biomedical Technology* exhibition will deal with topics such as DNA, the Human Genome Project, and personalized medicine in the Genomics section, and stem cells and cloning in the section on Prosthetics, Therapies, and Cures. As these exhibits are developed and tested, we will need to keep the following general issues in mind. Because we were not able to triangulate these literature review findings through interviews with GLSC visitors, they should be interpreted cautiously and, if possible, investigated in greater depth with visitors during formative evaluation.

Understanding genetics

Most adults and older children have a limited understanding of genetic terms and concepts, and younger children may have little or no understanding of even the basics of genetics. For instance, surveys of British students (14 to 16 years old) found that most had a very limited understanding of the function, structure, and locations of genes (Lewis, Leach, & Wood-Robinson, 2000a). Also, many students felt that different types of human cells, because of their different functions, contain different genetic information (Lewis, Leach, & Wood-Robinson, 2000b). Students also failed to differentiate between a gene (i.e., as a chemical sequence) and its effect or expression as a characteristic or trait (Lewis & Kattmann, 2004). There have been a few detailed studies of adults' understanding of genetic concepts (e.g., Emslie, Hunt, & Watt, 2002; Richards, 1996).



These suggest that adults' understanding of abstract genetics concepts is also limited, but that adults have an easier time discussing and understanding inherited traits within the context of their own families' histories.

Metaphors and popular culture

Despite their limited understanding of the abstract science of genetics, visitors may still attach a range of meanings to terms like “gene” and “DNA” based on their exposure to these concepts through popular culture. For instance, authors have catalogued the use of metaphors in presenting genetics to the public (e.g., Liakopoulos, 2000) and studied a range of other ways that the public encounters genetics in popular culture (e.g., Love, 1996; Turney, 1998; Van Dijck, 1998). Some authors have emphasized potential problems when people's understandings and feelings about genetics are heavily influenced by popular culture (e.g., Nelkin & Lindee, 1995). However, research about college students' responses to metaphors found that many respondents rejected the deterministic and potentially discriminatory implications of, for instance, the blueprint metaphor for the human genome (Condit, 1999). (The blueprint metaphor portrays the genome as a complete set of plans for human development, ignoring the many influences that the environment plays in this process. Many of Condit's respondents rejected a literal interpretation of the metaphor, citing a range of factors that could, in their minds, override the influence of genetic inheritance.)

Ethical and moral issues

As discussed in the [Controversies and Dilemmas](#) section, GLSC visitors had varied perceptions of potential ethical and moral controversies regarding topics for the new *Biomedical Technology* exhibition. Various authors have discussed ways that religion (Cole-Turner, 1999), race (Jackson, 1999), and family issues (Juengst, 1999), influence people's perceptions of the Human Genome Project.

Once the team determines exactly which topics and concepts will be included in the new exhibition, we will want to revisit some of these references to help guide the development, design, and testing of exhibit units.

A more specific discussion of GLSC visitors' understanding of personalized medicine, stem cells, and cloning are included below.

Knowledge hierarchy about the role of genetics in medicine

What follows is a general knowledge hierarchy for visitors' understandings of the role of genetics in medicine. The hierarchy suggests some challenges and opportunities the team will face as they try to develop exhibits about the role of genetics in medicine.

Level Zero: “I don't know, and I don't care.” Although younger respondents were often at this level, adult visitors were most often at Level One or Two. Adults were at least interested in the topic of genetics in medicine, even if their knowledge was very limited and their opinions were sometimes stronger than their understandings.



Level One: “**I was wondering...**” These visitors expressed an interest the roles that genes play in health and medicine, but had not followed up on their interest, sometimes because the subject seemed so intimidating to them.

Level Two: Incomplete or incorrect understanding. As discussed above, the literature suggests that most visitors have very incomplete and often incorrect understandings about the role that genetics plays in health and in modern biomedical technology. It also suggests that the visitors’ understandings may be shaped by metaphors used in the media, and that visitors may have opinions and beliefs about aspects of genomics they do not completely understand. In fact, as medical genetics plays a larger role in their lives, people are often confronting decisions about topics they barely understand (such as the tests for inherited diseases offered to parents of newborns).

Level Three: Basic understanding, such as “the diagnosis and treatment of genetic diseases is a growing part of medicine and public health, including testing of newborns for genetic diseases and the diagnosis and treatments of cancer and cystic fibrosis.” We suggest that visitors will have an easier time understanding these genomic concepts through case studies of specific medical issues. In other words, the scientific concepts will be introduced in a practical context, much like what visitors someday may have to deal with as part of their own lives. Also, case studies can be an effective way of playing up the biomedical technologies used in diagnosis and treatment.

Level Four: More sophisticated understanding, such as “researchers continue to study ways in which genes influence human health, and their research is paving the way to new diagnoses and treatments. This version of the Level Four understanding combines two of the learning goals for genomics. To reach this level, many visitors will need to: (a) overcome tendencies to see genes as destiny, developing a more flexible view of the interplay of genetics and environment, and (b) accept the idea that research in many areas is on-going and has not yet resulted in widely available treatments. We place these messages at Level Four because they focus on the uncertain process of biomedical technology development.

Level Five: Very sophisticated understanding. At this point, we’re not sure what general concepts to put at Level 5.

Personalized medicine

Personalized medicine is a relatively new approach to treating patients. Personalized medicine uses detailed knowledge of the human genome to test specific stretches of DNA in order to assess a patient's risk of disease, or reaction to potential treatments.

Among our sample of respondents, only adults in the medical field said they recognized the term “personalized medicine.” Even the medical professionals did not always have a full



understanding of the term (e.g., to the level of testing patients for specific genes and proteins). Most non-medical professionals said they had never heard of the term.

That said, when we asked adult respondents to take a guess at the meaning of the term, many came up with descriptions that were at least partially correct, and a few correctly guessed that personalized medicine involved using a knowledge of people's genetic make-up to decide how to treat them. It seems the term "personalized medicine" will be a useful one for helping visitors make sense of this exhibit.

Knowledge hierarchy about personalized medicine

This hierarchy integrates what we learned through discussions with visitors with the messages being developed for the new exhibit unit on personalized medicine.

Level Zero: **"I don't know, and I don't care."** Many respondents told us they had never heard of personalized medicine before we talked with them.

Level One: **"I was wondering...."** Based on our discussions with visitors, many of them became curious about this topic.

Level Two: **Incomplete or incorrect understanding.** As stated above, visitors who started an interview at Level Zero, when asked to guess at the meaning of personalized medicine, often were at least partially correct in their guesses. However, helping visitors reach the next level may be difficult, since it involves having or developing a fairly sophisticated understanding of how genetics works.

Level Three: **Basic understanding, such as "small differences in our genes affect the ways in which we get sick and react to drugs, and researchers are learning to use genetic information to develop personalized drug therapies."** This basic understanding combines two of the learning goals for the genomics section of the exhibit. To reach this level, many visitors will need to: (a) have some understanding of the roles genes play in the human body; (b) overcome tendencies to see genes as destiny, developing a more flexible view of the interplay of genetics and environment, and (c) accept the idea that research in many areas is on-going and has not yet resulted in widely available treatments.

Level Four: **More sophisticated understanding, such as "gene expression microarrays are a recently developed biomedical technology that allows doctors to quickly tell which genes a person has and which of those genes are currently active."** To reach Level Four, visitors would need to develop an understanding of the role that a specific type of biomedical technology plays in genomic medicine. (They would need to understand what the technology does, but not necessarily how it does it.)

Level Five: **Very sophisticated understanding, such as, "although researchers now have a complete list of human genes, they still have lots to learn about how small variations within the DNA of individual genes influence human health."** A



Level Five understanding emphasizes how much scientists still must learn about how the genome influences human health.

Prosthetics, Therapies, and Cures

In this section, discuss our findings about two existing exhibits, prosthetics and FES. We also summarize our discussions with visitors about two topics that will be included in the new exhibition, stem cells and cloning. Because this section of the exhibition includes such a variety of subtopics, we cannot develop a useful knowledge hierarchy for the entire section.

Prosthetics

Prosthetics and implants are engineered to replace missing or damaged body parts. The most recent developments in prosthetics and implants include microprocessors, advanced biomaterials and/or living cells to enhance their function.

The existing prosthetics exhibit attracted lots of attention from both children and adults. Visitors connected with the prosthetic devices in a variety of ways. The strongest connections were made by visitors who had received a prosthetic or implant themselves, or who knew someone with a prosthetic implant. Other visitors focused more on the interesting shapes and identities of the devices (e.g., what body part they replaced). Children were often at least mildly grossed out by many of the devices—we often heard them say, “ewww...”—but they also told us these devices were gross in a fun kind of way.

Because of the limited interpretation adjacent to most of these devices, parents sometimes had difficulty explaining the prosthetics to their children. Although this sort of information was available in the computer interactive included with the exhibit, few visitors explored at the computers in much depth, and parents rarely used the computers to find answers to their children’s questions. In the redeveloped exhibit, it will be important to assist parents (and other visitors) by providing more and better context for the prosthetics, perhaps including diagrams right next to the devices showing where, and sometimes how, they would be implanted in or attached to the human body. It will also be important to present one or more human interest stories for these devices, so that visitor groups who do not have their own stories to share about prosthetics will be able to connect on the affect level. Again, some of these stories were available through the computer programs, but were rarely accessed by visitors.

For a more detailed discussion of our findings and recommendations about the Prosthetics exhibit, see Appendix G.

Knowledge hierarchy about prosthetics

This hierarchy integrates what we learned through discussions with visitors with the messages being developed for the new introductory unit on prosthetics.

Level Zero: “I don’t know, and I don’t care.” We met very few visitors at this level.

Level One: “I was wondering...”. Once they saw the prosthetic devices, most visitors reached at least Level Two. (Some stayed at this level, because they couldn’t find convenient answers to their questions.).



Level Two: Incomplete or incorrect understanding. Most older children and adults had at least a general understanding of several types of prosthetic devices and implants (e.g., limbs and artificial hearts). Therefore, it seems appropriate to set the basic understanding (Level 3) at a slightly higher level than it is in the current exhibit. Younger children’s misunderstandings (e.g., thinking the devices were real human organs or not knowing where they fit) could be better dealt with by parents if the exhibit provided more effective contexts for the devices on display.

Level Three: Basic understanding, such as “prosthetic devices are becoming more functional and comfortable through the use of new materials and computer chips.” This understanding seems well within reach for most visitors and provides strong support for the big idea of the exhibition. (During formative evaluation, we will want to test whether “computer chip” is the best term to use here.)

Level Four: More sophisticated understanding, such as “researchers are finding ways to improve the body’s incorporation of plastic and metal implants by coating them with adult stem cells to promote new growth.”

At this point, we are not sure what general concepts to put at Level 5. (It may be a more complete explanation of the role of human cells in implants.)

Functional Electrical Stimulation (FES)

Functional Electrical Stimulation (FES) helps patients overcome paralysis using wires to stimulate damaged nerves and muscles and a computer microchip to control the motion of the re-energized body part. Advances in FES produce devices that are smaller and more rugged, yet complicated enough to produce finer levels of muscle control.

The existing FES exhibit included a button-pushing interactive that showed visitors how difficult it was to coordinate the movement of legs and a video that showed the application of FES within the life of a man who had lost the use of his legs. Visitors seemed to enjoy the interactive, although they often were frustrated by their inability to achieve make the legs “walk” smoothly. The video was enjoyed especially by adults and older children, and many viewers seemed to achieve an empathetic connection with the patient as well as a better understanding of FES.

Talking with children, it became clear that their limited understanding of the neuromuscular system was a barrier to their understanding of FES. Although they often knew or guessed that that an electric shock would make a muscle twitch, many children and even some adults did not seem to understand the role of electricity in the nervous system. Even basic terminology seemed a bit confusing to visitors. For instance, one respondent used the term, “electrolysis,” to describe FES. Older children often understood that the brain played a role in controlling muscles, but they couldn’t always remember that nerves connected the brain with muscles—one young respondent guessed the connection was through veins or blood vessels. However, some parents were quite helpful with explaining the brain-nerve-muscle system to their children. The revised exhibit will need to explain some basic human biology if visitors are going to understand and appreciate FES, perhaps by giving parents diagrams and other resources to help them explain the basics to their children. Younger visitors (and some adults) remembered bits and pieces of the system, but



they will need help constructing or reconstructing their understanding of the system based on those fragments.

For a more detailed discussion of our findings and recommendations about the FES exhibit, see Appendix G.

Knowledge hierarchy about FES

This hierarchy integrates what we learned through discussions with visitors with the messages being developed for the new exhibit unit on personalized medicine.

Level Zero: **“I don’t know, and I don’t care.”** Many respondents told us they had never heard of FES before we talked with them.

Level One: **“I was wondering…”** Based on our discussions with visitors, many of them became curious about this topic.

Level Two: Incomplete or incorrect understanding. Adult visitors sometimes stumbled over the terminology (like the woman who talked about “electrolysis”), and there were indications that many adults rarely thought much about the role of electric signals in controlling muscles. One of the factors that will limit children’s understanding of this topic is their incomplete understanding of how the nervous and muscular systems work together to produce movement. For instance, most children knew or guessed that a muscle would twitch when an electric shock was applied. Many also knew that the brain played a role in controlling muscles. However, elementary aged children had, at best, a limited understanding of the nervous system and how it uses electrical signals to stimulate muscles.

Level Three: Basic understanding, such as “to return muscle control to patients who have been paralyzed, Functional Electrical Stimulation (FES) uses electrical wires to tell muscles when to move and computer chips to coordinate muscle movements—the wires act like nerves, and the computer chip acts like the brain.” This Level Three understanding focuses on understanding the basics of FES, which should be accessible to most visitors with appropriate support.

Level Four: More sophisticated understanding, such as “at Case Western Reserve University, researchers are designing FES systems that are as complicated as a modern car, rugged enough to last in a body for decades, and tiny enough to fit inside the patient’s body.” This Level Four message focuses visitors’ attention on advances in FES, supporting the big idea for the exhibition.

Level Five: Very sophisticated understanding, such as “doctors, engineers, and technicians are constantly scouting new technologies to make FES better.” This Level Five message focuses visitors’ attention on part of the process that produces better FES devices—bringing together advances from other fields.



Stem cells

Most GLSC respondents had a limited understanding of where stem cells are in humans and of how they function. Asked about their understanding of stem cells, most respondents told us that stem cells were extracted from aborted fetuses and were used to treat various diseases (which they often could not specify). Respondents expressed surprise and interest when we told them that stem cells also are found within adults' bodies, and that they are used for treatments such as bone marrow transplants.

Visitors most often discussed issues related to aborted fetuses when discussing controversies related to stem cells. As with other potentially controversial topics that we discussed with visitors, respondents said they would like to see impartial, scientific information about the types and uses of stem cells in the new exhibit, as well as discussion of pros and cons of stem cell therapies.

Cloning

There were indications that most GLSC respondents thought of cloning as “making another me.” In other words, cloning meant making complete human beings (or in one case, a complete sheep). Only one respondent talked about cloning on the cellular level.

Emerging Infectious Diseases

Because of limited time and a lack of existing exhibits about this topic, we spent relatively little time discussing infectious diseases with GLSC visitors. However, as noted earlier, there were indications that visitors accepted “new” diseases, like avian flu, as appropriate to an exhibit about biotechnology, in part because doctors were still looking for cures for them. Turning to the science education, evaluation, child development, and medical education literatures, we were able to find some ideas about how GLSC visitors, both young and old, may think and feel about infectious diseases and the organisms that cause them. Because we were not able to triangulate these literature review findings through interviews with GLSC visitors, they should be interpreted cautiously and, if possible, investigated in greater depth with visitors during formative evaluation.

Understanding infectious diseases

The literature suggests that, for both children and adults, understandings about illness will be partly scientific and partly affective in nature.

Young children develop parallel approaches to explaining illness. One approach seems to precede a more scientific understanding. Sometimes called, “contagion,” this approach uses physical causes to explain illnesses that you can “catch” from other people. Another concept, first explained by Piaget, is called “immanent justice.” This concept is invoked when children's moral judgments about fairness and guilt override more scientifically inclined explanations. For instance, young children sometimes feel guilty about being ill, because they perceive the illness as a punishment for some real or imaginary transgression. Kister & Patterson (1980) found that preschoolers were more likely than second and fourth graders to misapply the contagion concept to non-contagious illnesses and to injuries from accidents, and were less likely to understand how the distance between people affects the transmission of contagious illnesses. These younger children also were far more likely to use immanent justice to explain medical events. However,



all the children in the study used immanent justice to explain illnesses more often than they used it to explain injuries due to accidents (Kister & Patterson, 1980).

Although preschoolers frequently hear their parents talk about “germs,” Solomon & Cassimatis (1999) cited five studies as evidence that younger children have not really developed a biological germ theory of illness. Their preschool respondents seemed to believe that symptoms themselves were contagious (rather than transmitted by germs). They also did not see germs as living, biological entities in the ways that animals and plants are alive (Solomon & Cassimatis, 1999).

Sigelman, Maddock, Epstein, & Carpenter (1993) studied the development of older children’s understanding of the physical causes of diseases, including AIDS, colds, and cancer. Understanding of the risk factors for these diseases increased from age nine years through college. Although younger children understood many of the factors that caused each of the diseases, they often inferred that risk factors for one disease also caused the others. Children’s knowledge of each disease seemed largely independent of their knowledge of the others (Sigelman et al, 1993).

Although much of the literature on health communication focuses on explaining the science of illness to children, Whaley (1999) argues that this may not be the most effective approach for children who are affected by illness. He cites evidence that children may find the more scientific knowledge to be of little use and may prefer explanations that more specifically address their psychosocial concerns (Whaley, 1999).

Susan Sontag was one of the first to emphasize the more affective aspects of adults’ understandings of illness through her books on metaphors for illness (Sontag, 1990). She discussed how the metaphors and myths surrounding cancer and other diseases often increase patients’ suffering. This seems particularly true of the so-called “metaphors of empowerment” that encourage patients to resist disease by will power. The academic literature continues to study issues related to metaphor and disease. For instance, Weiss (1997) found that, among Israeli adults, metaphors of "pollution" and "transformation" were used for AIDS and cancer, but that heart disease was more often described metaphorically as a defect in the "body machinery.” Wallis & Nerlich (2005) found that, within the United Kingdom, media metaphors for SARS depicted the disease as a single, unified “killer,” rather using the militaristic metaphors commonly used to describe treatment of diseases (like “army” or “force”) or the more judgmental metaphors like “plague.” Writing from a nursing perspective, Czechmeister (1994) called cancer metaphors “two-edged swords” that, as Sontag claimed, “may be negative forces, creating confusion, stereotype and stigma,” but that also are “fundamental to individual and collective expression” (p. 1227). She argued that, “awareness of the expressive function of metaphor provides a valuable focus for listening to and understanding the experience of the patient” (p. 1226).

Although the team still must consider the roles that metaphor may play in interpreting this section of the exhibit, it seems clear that visitors will introduce their own metaphors as they discuss the exhibits within their groups and perhaps contribute to any discussion-oriented interactives included in this section. Children — and undoubtedly adults — will also introduce their own moral judgments and psychosocial interpretations as they try to make sense of the



exhibits. As we prototype and test these exhibits, we need to be aware of how these affective responses influence visitors' perceptions of the exhibits' messages.

Understanding microbes

In many museums and classrooms, "microbe" is the preferred term for a range of microscopic organisms, including bacteria, viruses, and what laypeople often refer to as "germs." Visitors' understandings of the concept "microbe" may, in turn, affect their understandings and feelings about a range of concepts in biotechnology (Simonneaux, 2000) and biomedical technology.

A 1999 summative evaluation of an exhibition at the Smithsonian Institution demonstrated both the limited knowledge that visitors have about microbes and the potential for engaging exhibits to increase that knowledge (Pekarik, Smith, Doering, & DiGiacomo, 1999). The summative evaluation of the *Microbes* exhibition in the Smithsonian's International Gallery used a pre-visit/post-visit design, asking visitors the following questions both before and after their visits to the exhibition:

What are microbes?

How are microbes different from each other?

How can you protect yourself from microbes?

Quoting from the report:

Since the only difference between entering and exiting visitors in the aggregate is the fact that one group saw the exhibition and the other did not, any differences between entrance and exit samples in the answers to these questions should reflect what visitors learned in the exhibition.

While over one-quarter (27%) of entering visitors did not know what microbes are, fewer than one in ten (9%) left without knowing. Similarly, while 43 percent of entering visitors could not say how microbes are different from each other, only 9 percent of exiting visitors were similarly handicapped. (Pekarik et al, 1999, p. 5)

In a detailed study of how French secondary students think and feel about microbes, Simonneaux (2000) found students' knowledge to be fragmentary and "conditioned by the status they attributed to illness, by their hygiene-oriented culture, by their layman's and school knowledge, by personal experience (episodes), by socio-cultural mediation, and finally by linguistic confusion" (p. 635). Their main sources of information about microbes included an AIDS awareness campaign, TV news and documentaries, a television cartoon series that personified bacteria and viruses, and family conversations about vaccinations and the causes of illnesses experienced by family members. School learning also played a role in introducing the students to certain concepts, such as the role of bacteria as decomposers.

So far we have not found any similar studies undertaken with American respondents. Although we would also expect American children's knowledge to be similarly incomplete, and in some ways inaccurate, because of differences in American popular culture and school curricula, the specifics of their knowledge may be different from the French students. As we test prototypes for the Emerging Infectious Disease exhibit, we should be aware of visitors' incomplete or



inaccurate knowledge of basic concepts and how this affects their understandings and feelings about the biotechnology exhibits.

Knowledge hierarchy about application of biomedical technology to infectious diseases

In this section, we present a knowledge hierarchy for visitors' understandings of the interrelationships between biomedical technologies and infectious diseases. This hierarchy is based partly on our discussions with visitors about [The Meaning of Biomedical Technology](#), cited above, and partly on the learning goals being developed for the exhibition.

- Level Zero:** **“I don’t know, and I don’t care.”** These visitors were unaware that biomedical technology is being applied to infectious diseases. They were familiar with BMT applied to other fields, and they had some understandings about infectious diseases, but they have never made the link between these two areas of knowledge. Generally, their understanding of biomedical technology was very limited, including medical “machines” and not much else.
- Level One:** **“I was wondering....”** Several visitors had heard that BMT could be applied to infectious diseases, and they had some questions about this topic—but they as yet had not found answers to their questions.
- Level Two:** **Incomplete and/or incorrect understanding, such as “BMT has been applied to avian flu, but not malaria.”** We talked with some visitors who expressed this belief. They seemed to have been exposed to media reports that showed how advanced technologies were being applied to emerging diseases, but they were unaware of continuing research on “old” diseases, like malaria. Also, potential visitors are likely to have incomplete understandings of the emerging diseases themselves, such as how they are spread, and or the interventions that are used to prevent and treat them (e.g., believing that vaccines cure infections, rather than prevent them).
- Level Three:** **Basic understanding, such as “advances in biomedical technology are improving doctors abilities to predict, identify, treat and contain infectious diseases.”** This version of a Level Three understanding would strengthen the link between biomedical technology and infectious disease, and it would broaden visitors' understanding of the range of ways that BMT can be applied to infectious diseases.
- Level Four:** **More sophisticated understanding, such as “biomedical technology researchers are applying advances in genomics, materials science and high-speed computing to improve prevention, containment, and treatment of infectious disease.”** These Level Four understandings are more specific about the specific types of technologies applied to fighting infectious diseases. They would require developing a deeper understanding of both the technologies involved and the diseases to which they are applied.



Level Five: Very sophisticated understanding, such as “by using tools like gene expression microarrays to understand the genome of an infectious organism, doctors can better tailor treatments to a specific patient’s disease.” Level Five understandings will be even more specific to both the technology and the disease. We would expect only medical professionals, other scientists, and very interested non-professionals to reach this level.



DISCUSSION: THREE MODELS FOR THINKING ABOUT THE *BIOMEDICAL TECHNOLOGY* EXHIBITION

This section analyzes what we learned by observing and talking with visitors in the exhibits in light of findings from the literature review. Based on this analysis, we discuss implications for the new *Biomedical Technology* exhibition.

This discussion begins by presenting three very different models for thinking about the new exhibition. Deborah Perry's model addresses the question, "What makes exhibits fun?" By using this model, the team can create exhibits that are engaging for all ages. Zahava Doering's Entrance Narrative model is also about how visitors experience exhibits, but it starts with what is inside the visitor rather than with the exhibit itself. Finally, the Boston Museum of Science Model for Technology Literacy in Museums addresses a completely different question: How can museums help their visitors consider the full range of technology-related issues that would be of interest to a technologically literate person?

Making Exhibits Fun

There were many indications that the current *Medical Technology* exhibits were not much fun compared with the exhibits in other parts of GLSC. There were buttons to push, computer screens to navigate, and things to peer into, but visitors did not have nearly as much fun here as at the adjacent *Sports Technology* exhibits or at the highly interactive *Science Phenomena* exhibits on the next floor up. The research on interactive exhibits suggests that it was much more than that.

Inspired by work by Mark Lepper and Thomas Malone at Stanford University (Malone, 1980, 1981; Malone & Lepper, 1987), Deborah Perry identified six important components that help museums and science centers make learning fun, satisfying, and successful for visitors (Perry, 1989, 1992, 1993 b and c). An exhibit experience, interactive or otherwise, should seek to maximize as many of these components as possible:

- **Curiosity:** Surprise and intrigue the visitor.
- **Confidence:** Help visitors feel safe and smart.
- **Challenge:** Encourage visitors to do or learn something new.
- **Control:** Help visitors feel "in charge."
- **Play:** Encourage playfulness and sensory exploration.
- **Communication:** Stimulate meaningful conversations.

Looking at the existing *Medical Technology* exhibits, they seem relatively effective on two of these components: curiosity and communication. Visitors were clearly curious about many



aspects of the human body and the technologies used to peer inside and understand it. Also, the medical artifacts, specimens, and procedures on display inspired many meaningful conversations about visitors' own experiences with medical technologies.

At least some of the exhibits were also relatively effective on a third component, confidence. Several exhibits presented familiar medical technologies that parents and former patients felt comfortable explaining to other members of their groups. However, the existing exhibits were much less effective at inspiring visitor experiences with the remaining three components: challenge, control, and play. The Perry Model predicts that by putting visitors in control, providing them with appropriate challenges, and inspiring playful behaviors, visitors will have more fun, spend more time, and learn more from the exhibits.

Visitors' Entrance Narratives

Given participant responses to many issues, it seemed in our discussions with visitors that there were underlying values being expressed, specifically ***a strong belief in progress in medical technology and in the personal benefits of such progress.***

Visitors come to museums with *entrance narratives*—perspectives that shape their museum experiences (Doering, 1999). The entrance narrative, or internal story line that visitors bring with them, has three distinct components:

- a basic framework, i.e., the fundamental way that individuals construe and contemplate the world,
- information about the given topic, organized according to that basic framework, and
- personal experiences, emotions, and memories that verify and support this understanding.

In the case of the existing *Medical Technology* exhibition, many respondents' framework seemed to be medical progress, and many visitors told us personal stories that supported that framework.

Some researchers claim that exhibitions are often inefficient and ineffective methods for communicating new information or changing attitudes, but they are powerful tools for *confirming, reinforcing, and extending* existing beliefs (Pekarik, Doering, & Bickford, 1995). The most satisfying exhibitions for visitors seem to be those that resonate with visitors' entrance narratives and confirm and enrich their existing views of the world. "Part of the satisfaction people find in visiting exhibitions seems to reflect the experience of having one's ideas validated in a serious public forum, since individuals tend to visit the exhibitions that agree with their viewpoint and to express indifference or hostility towards the ones that do not" (Pekarik et al, 1995, p. 10).

Presenting Technology in Science Centers

Science museums and science centers have begun exploring ways in which they can contribute to the technology literacy movement (Friedman, 2002). According to the International Technology Education Association (ITEA) Standards, a technologically literate person is one who "understands, in increasingly sophisticated ways that evolve over time, what technology is, how it is created, and how it shapes society and, in turn, is shaped by society." Those goals overlap, to at least some extent, with the goals of the *Biomedical Technology* exhibition.



As they developed plans for new technology exhibitions at the Museum of Science in Boston, Museum of Science staff developed a new model for presenting technology in museums (Bell & Rabkin, 2002). They argued that, "To do a good job at technology education, a science center must show what technology is and what is going on in technology today. It must provide hands-on experience in design and engineering processes. It must create a forum for discussion of the societal issues raised by technology" (p. 27).

To reflect these three goals, they created a three-part model for technological literacy in museums (Fig. 1). Here's how they describe the three components and relate them to the technology literacy movement.

In the broadest sense, Showcase themes deal with "what" questions, Playground themes deal with "how" questions, and Forum themes deal with ways to answer "why" or "why not." The new definitions of technological literacy call for educational vehicles that integrate "what," "how," and "why" kinds of thinking.

The three parts of this new definition of technological literacy have been implemented individually in various science centers throughout their history. However, they have been seen as alternative approaches rather than components that are integrated into an overall experience. Individually, these alternative approaches have been found lacking in one way or another. While exhibitions that principally showcase technology may have educational aspects to them, they often have been viewed as corporate promotions. While science center exhibits that create a playground of learning experiences can address important thinking skills connected with engineering design or the use of technology, these exhibits often remove the real-world context and consequences from the experience. Finally, science centers creating forums for discussion of societal issues raised by new technologies have faced difficulties with an education staff used to the processes of science but not the realms of values, ethics, and politics. These efforts have all focused on one or another aspect of the three aspects of technological literacy. The new definitions of technological literacy suggest the importance of using a model that combines all three, an approach that we have adopted at the Museum of Science (Bell & Rabkin, 2002, p. 27).



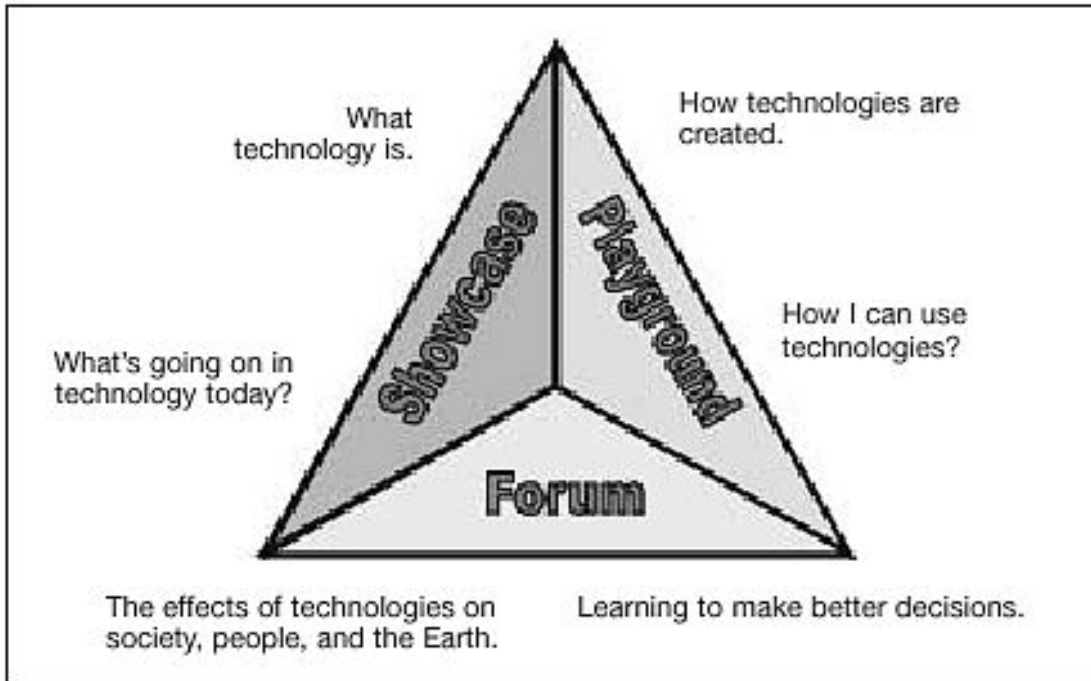


Figure 1. The Boston Museum of Science Model for Technology Literacy in Museums (from Bell & Rabkin, 2002).

The current plans for the *Biomedical Technology* exhibition seem to contain all three elements of the Museum of Science model, and it may be useful for the exhibit team to think in greater depth about how the three themes interrelate for each of the major technologies included in the new exhibition.



RECOMMENDATIONS

The recommendations in this section are general, and apply to a range of exhibit topics. Specific recommendations for redeveloping existing exhibits are included with the individual exhibit evaluations in Appendix G.

Keep focusing on the big idea for this exhibition: “Rapidly improving biomedical technologies give doctors new tools to improve personal and public health.” Although the grant proposal discusses a broad range of issues (like cutting-edge research, ethics, and how new technologies are developed by interdisciplinary teams), the team must present these subsidiary concepts through the lens of the big idea—especially given how little visitors know about biomedical technologies and where they come from. Every exhibit element must support visitors’ developing understanding of the project’s big idea.

Present biotechnology research and development in ways that complement and build on most visitors’ beliefs in medical progress. As visitors told us, this does not have to be an exhibit that only shows cutting edge technologies—that’s not what visitors expect or desire. However, also be aware that visitors will disagree about which technologies represent progress, and which technologies present controversies and dilemmas for researchers, medical doctors and their patients. Although some visitors will want to avoid any controversies, others will be eager to express their own views. Specific points to keep in mind:

- **Think carefully about the goals** for showing the latest technologies and those currently under development. The team also needs to consider how the examples they chose will resonate with visitors’ entrance narratives about BMT.
- **Pick and choose** where and how to show the very latest technologies.
- **Remember that the most compelling aspects** of biomedical technologies may be:
 - Examples that show great leaps forward—really major progress, the first of its kind, allowing doctors to do things they couldn’t do before.
 - Examples most likely to have an impact on visitors and their families and friends (even though the progress may be more incremental).
- **Help visitors recognize which technologies are at the cutting edge.** Explain what puts these new technologies at the edge, and what significance these new technologies may bring to their lives.
- **Make plans now to keep the exhibit updated.** In some cases, these plans may include leaving space or planning for replacements for new technological developments. In other cases, it may mean carefully choosing the wording of labels, so the text is still true, and reads as current, five or ten years after exhibit opening.



Carefully consider the goals for any dialogue and debate exhibits that are developed. For instance, are these exhibits trying to:

1. Demonstrate that GLSC cares about and respects visitors' views and opinions about the issue?
2. Expose visitors to a range of opinions about the issues?
3. Help visitors gain more respect for other people's views and opinions?
4. Demonstrate that the research & development community as a whole considers many points of view when deciding how to proceed?
5. Give visitors a chance to think more deeply about the issues?
6. Influence or change visitors' opinions?
7. Give visitors a chance to express their own views...
 - a. ...to others within their own groups?
 - b. ...to other visitors, directly?
 - c. ...to the larger science center audience, asynchronously?
 - d. ...to the research & development community?

Each of those goals would argue for a slightly different approach, and each would bring its own challenges and potential benefits.

Remember that dialogue and debate exhibits will provide very different experiences for those who participate directly, and those who stand back and read and watch. The team needs to consider how this range of experiences fits with their goals. Possible outcomes of the exhibit, which need to be considered up front and then test for during prototyping, include:

- **What are the outcomes for those who have not thought much about the issues before?** Do they feel better informed or resent the attempts to shape their opinions?
- **For those who already have an opinion,** does the exhibit polarize visitors and confirm their worst fears about those who disagree with them, or does it help them become more accepting of other points of view?
- **After viewing or using the exhibit, how do visitors feel about GLSC?** Do they appreciate the Center's broad-mindedness, or fault it for giving voice to opinions they consider to be ignorant and shortsighted?

Be aware of the emotional content of biomedical technology for many visitors. More than most exhibits at GLSC, the new *Biomedical Technology* exhibition will be personal for many visitors, especially adults. Both children and adults will also introduce their own moral judgments and psychosocial interpretations as they try to make sense of the exhibits. As we prototype and test exhibit units, we need to be sensitive to the ways in which these affective responses influence visitors' perceptions of the exhibits' messages.

Find ways to make biomedical technologies more meaningful to visitors who have not had previous experience with them—especially members of the target audience and younger children. This may involve introducing carefully chosen stories about the impact of biomedical technologies on individual patients.



Use the knowledge hierarchies presented in this report to develop exhibits that motivate and support learning by visitors with a range of interests and knowledge. For instance:

- **Entice** Level Zero visitors with intriguing opportunities for engagement with the exhibits.
- **Answer** Level One visitors' top-of-mind questions about the technologies on display.
- **Provide** Level Two visitors with new, more scientifically correct explanations of basic BMT concepts.
- **Expand** Level Three visitors' basic understanding to include the full scope of the big idea: "Rapidly improving biomedical technologies give doctors new tools to improve personal and public health." Visitors need to understand both the scope of BMT (beyond the devices) and the range of medical challenges that BMT addresses.

Carefully consider the potential impacts of metaphors used in the exhibition. These include both metaphors introduced by the team to help visitors make sense of the exhibits' content, and the metaphors used by visitors as they talk with other visitors.

Use a range of carefully chosen media to help visitors understand basic concepts of biomedical technology. This may be as simple as diagrams that help children and their parents locate internal organs, and as complex as the DNA Zoom, which helps visitors understand the relative sizes and locations of DNA, genes, and chromosomes. The idea is to provide key concepts just-in-time to illuminate the core issues of the exhibits.

Use the Perry Model to make the exhibits more fun. In particular, give visitors more control over their interactions, present them with appropriate challenges, and provide them with more opportunities to play. These additions may help visitors look past the limited range of physical engagements possible when displaying complex technologies and biological specimens.

Carefully chose and explain the terms for professionals involved in biomedical technology research and development. Although the term "clinician" seems likely to confuse visitors, either "researcher" or "investigator" could be used to refer to professionals who develop new technologies. Regardless of which terms are used, the team should define, qualify, and illustrate their intended meanings using labels, photos, and multimedia presentation.



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APPENDIX A: PHOTOS OF THE EXISTING *MEDICAL TECHNOLOGY* EXHIBITION



Figure A1. Existing *Medical Technology* exhibition is on the right, and the *Sports Technology* exhibition is on the left.



Figure A2. Existing *Medical Technology* exhibition. Medical Imaging is on the right, MRI in the center, and Prosthetics on the left.





Figure A3. Overview of *Medical Technology* exhibition, looking southeast to northwest. MRI is in the center, Ultrasound, Microscopes, and Endoscope on the west wall.



Figure A4. Genetic Engineering exhibit along the south wall. Although this exhibit is discussed in the text, it will not be reused in the new *Biomedical Technology* exhibition.





Figure A5. DNA Fingerprinting exhibit. Although this exhibit is discussed in the text, it will not be reused in the new *Biomedical Technology* exhibition.

Additional photos of individual *Medical Technology* exhibits may be found in Appendix G, which is a separate document entitled BMT1FinalReportAppendixG01.doc.



APPENDIX B: TOPICAL FRAMEWORK

Topical Framework for the
Front-End Evaluation
of the Great Lakes Science Center
Biomedical Technology Exhibit
Selinda Research Associates, Inc.

March 23, 2006

A topical framework is a list of issues or topics we will explore during the front-end evaluation. It is phrased as a series of questions we will try to answer by observing and talking with visitors and GLSC staff, and by reviewing the relevant literature. (Note: These are questions we will answer, not the questions we will ask visitors.)

Research Question

What can we learn about potential visitors' understandings of, and connections with, biomedical technology that will help the exhibition team develop an engaging and provocative exhibition?

Topical Framework Questions

1. In what ways do visitors' think and feel about biomedical technology (BMT), the application of physics, engineering, math and biology to medicine?
 - a. How do visitors understand and think about BMT? How to they feel about BMT? If they are unfamiliar with the term, how do they try to make sense of it? How interested are visitors in learning more about the subject, and why might some visitors not be interested (e.g., intimidated by subject, bad experiences with BMT procedures, uncomfortable in medical settings, etc.)? To what are visitors' interests driven by scientific curiosity, engineering challenges, "Grossology" aspects, and/or the personal or altruistic desire to improve and save lives (their own and others)?
 - b. What do visitors know and feel about the disciplines that contribute to advances in BMT, and about the interrelationships among those disciplines?
 - i. How do visitors think and feel, about the high-powered computers that are becoming so important to the practice of medicine? In what ways do young visitors relate BMT computing to their own interests in computers and related technologies?
 - ii. In what ways, and to what extent, do visitors appreciate and understand how doctors use physical phenomena to aid in diagnosis and treatment? How do



visitors think and feel about the physical phenomena and the technologies that detect and display those phenomena?

- iii. How do visitors think and feel about the field of engineering and its relationships to medicine and biology? In what ways, and to what extent, do visitors appreciate and understand the ways that advances in engineering, especially biomaterials and miniaturization, have contributed to BMT?
 - iv. How do visitors think and feel about the field of genomics and its role in BMT, including pharmaceuticals? In what ways, and to what extent, do visitors appreciate and understand the ways that advances in our understanding of the human genome and ability to manipulate DNA are contributing to medical practice? In what ways, and to what extent, might visitors' lack of familiarity with (and perhaps their intimidation by) genetic terms and concepts interfere with their understanding and appreciation of the exhibits? What are ethically sensitive or potentially controversial topics in the minds of visitors?
- c. As the team further develops the content for the exhibition, what key concepts emerge that may serve as gateways or barriers to visitors' understanding and appreciation of the exhibits? Which of these concepts are visitors most aware of and most interested in, and why? How do they understand and think about key concepts that will be discussed, illustrated, and applied in the exhibits? Which concepts do visitors associate with ethically sensitive or potentially controversial topics or issues?
2. In what ways, and to what extent, do visitors appreciate and understand the impact that BMT has on patients' health, including saving lives?
- a. In what ways, and to what extent, do visitors appreciate and understand that BMT has made diagnosis and treatment less intrusive (i.e., surgery not required) and more effective? For those who have experienced one or more procedures, how do they feel about its intrusiveness and effectiveness? In what ways do these procedures seem ethically sensitive or potentially controversial to visitors?
 - b. On a more personal level, in what ways, and to what extent, do visitors appreciate and understand applications such as medical imaging, genomics, and replacing diseased or injured organs and tissues? Which of these topics are interesting to visitors, and what is the nature of their interest? Which of these topics do visitors find controversial or ethically challenging, and in what ways and to what extent might visitors be willing and interested in engaging in dialogue about these topics? What kinds of dialogues will resonate with visitors, and how should the team select topics for forum exhibits (see also 3.b., below)?
 - c. On a more global level, in what ways, and to what extent do visitors appreciate and understand that advances in BMT are being applied to detecting and treating infectious diseases globally? In what ways do visitors relate to these diseases, and to



what extent are they interested in potential solutions for these problems? (This topic may include either perennial disease problems, like malaria, AIDS, and polio, or emerging diseases, like bird flu.)

3. What can we learn about effective ways to present BMT in a science center setting?
 - a. What are effective ways to present controversial topics in an exhibit about BMT? What can we learn from the experiences of other science centers that have presented controversial topics, especially those that have developed forum exhibits where groups of visitors engage in dialogue?
 - b. In what ways do visitors want to relate to others within their social groups—and, for that matter, within other social groups? To what extent would they be interested in sharing stories, discussing ethical issues, or engaging in debate? How would they respond to being offered a structure to shape their discussions (such as being given roles to play)? What exhibit options have been tested at other institutions, and what has been learned from these earlier exhibits? (The options might range from informal face-to-face conversations and discussions to a range of technologically mediated dialogues where, for instance, individuals respond directly to the exhibit, read and respond asynchronously to other peoples' responses, and so forth.) What can we learn by watching and talking with visitors as they use the visitor-response exhibit in the BMT prototype area?
 - c. In what ways can telling the stories of actual patients advance the goals of the Biomedical Technology project? What issues might the team face in developing and exhibiting these stories? For example, do we risk being perceived as judging people based on their health status? In what ways can the team gain insight into these issues (e.g., individuals and organizations as advisors, visitor panels of medically challenged individuals, the published literature).
 - d. In what ways, and to what extent, might project goals be advanced by profiling individual Case doctors, researchers, and engineers? What challenges will GLSC face in developing and maintaining exhibits about particular doctors, researchers, and engineers?
 - e. In what ways would simulated medical settings (e.g., an operating room) and procedures (e.g., endoscopy) contribute to visitors' understandings of BMT and thus influence the effectiveness of the exhibits? What has been the experience of other science centers with these types of exhibits? How can GLSC balance the pros and cons of these exhibits, minimizing discomfort of some visitors while stimulating and satisfying the curiosity of others?
 - f. What is the range of visitors' reactions to real medical equipment, prosthetics, and graphic medical images? How might visitors' reactions influence the effectiveness of the exhibits? What has been the experience of other science centers, and how can GLSC balance the pros and cons of these exhibits?



- g. In what ways do visitors respond to mechanical interactives that metaphorically model applications of BMT (for example, a pulley system that embodies the principles that make tendon transfer work)? To what extent do visitors attend to and use the examples in the current exhibit, and do they think about these interactives in ways that help advance their understanding of the “real thing”?
 - h. How do visitors respond to AV and computers as modes of communication for biomedical techniques and procedures? Do some topics seem better suited to this approach? When looking at images, do visitors respond differently to real footage vs. simulations? What has been the experience of other science centers using alternative physical user interfaces (beyond trackballs and buttons)?
4. In what ways and to what extent are visitors aware of, and interested in, research & development of new BMT applications (as opposed to basic research in the individual disciplines)?
- a. In what ways, and to what extent, do visitors appreciate and understand the interdisciplinary development of new BMT applications? What do they know and feel about the disciplines that contribute to BMT research & development, and the ways in which BMT research & development is done?
 - b. Which aspects of current BMT research & development do visitors find most compelling? How current does a presentation have to be to seem “up-to-date” or “cutting-edge” to visitors? To what extent do visitors want and expect GLSC to be a place-to-go for current biomedical research & development? What challenges will GLSC face in developing and maintaining exhibits about current research & development?
 - c. To what extent are visitors aware of and interested in the places where BMT research & development is done? To what extent are visitors aware of Case Western Reserve University (Case) and its role in BMT research & development? In what ways might the BMT project challenge and expand visitors’ existing understandings of Case and the roles of universities in BMT research & development?
5. To what extent are young visitors (and their parents, guardians, and teachers) aware of and interested in potential careers in BMT?
- a. To what extent, and in what ways, do young people think about their own future employment opportunities in the field of BMT? What aspects of BMT appeal the young visitors? To what extent is their interests driven by scientific curiosity, engineering challenges, salary considerations, and/or altruistic desire to improve and save lives?
 - b. To what extent are young visitors aware of, and interested in, the kinds of work currently available in the BMT field? What types of jobs do they find most



- interesting, and why? What BMT jobs might they be interested in “trying out,” and what sort of employment simulation would be most appealing to them?
- c. To what extent are young visitors (and their adults) aware of, and interested in, the interdisciplinary nature of BMT careers? How does their awareness of interdisciplinary links influence their interest in a BMT career?
 - d. In what ways, and to what extent, are young visitors (and their adults) aware of and interested in learning about the pre-requisites to working in BMT? How might these pre-requisites be related to visitors’ current interest in, and knowledge and feelings about, higher education?



APPENDIX C: VISITOR OBSERVATION PROTOCOL

GUIDELINES FOR VISITOR OBSERVATIONS

BioMedTech Project

March 23, 2006

Observing and Interviewing Visitors

1. Select respondent(s). Throughout the course of the observations, it's still important to try to watch a *range* of visitors. When selecting respondents you want to make sure you are conscious of whom you choose to speak with. Look for:

- Age
- Gender
- Social Configuration
- Ethnicity

It's human nature to pick people who look like us. Two ways to make sure you're selecting a broad range is:

- Why am I selecting this respondent?
- Choose a visitor group that is completely different from the previous group you talked to (unless you have a reason for selecting a similar group).

Make note of the group characteristics on the top of the first page of the Observation Form.

2. Observe the selected group and take field notes detailing what they do and say. In your field notes, pay particular attention to:

- Physical engagements are all the physical things visitors do at an exhibit, for example, sitting, standing, looking, reading, pointing, touching, and manipulating trackballs. This also includes how long visitors spend at the various exhibits.
- Intellectual engagements are all the ways in which visitors engage cognitively with an exhibit, including thinking about, processing, and making meaning of their experiences. What mental processes do visitors seem to be using (observing, hypothesizing, appreciating, experimenting, comparing, contemplating, etc.)? In what ways do visitors seem to be thinking about and making connections with what they already know and have experienced?
- Social engagements are all the ways in which visitors engage with each other within the context of the exhibit, including verbal exchanges as well as body language. This could include directing attention, asking a question, coming up with an explanation together, reading a label out loud. We are interested in how visitors engage with each other, the types of teaching/learning and meaning-making interactions they participate in, and what they talk about, and how they talk about it.



- Emotional engagements are all the ways that visitors engage emotionally with the exhibit; examples include surprise, delight, awe, satisfaction, feelings of competence, intimidation, and frustration. By looking at emotional engagements, we can get a feel for visitors' primary emotional connections with the exhibit materials, as well as look at the role of play in developing and maintaining interest (and learning).

3. Complete the Observation Protocol -- Field Notes page

Take time to complete your observation notes. Fill in any missing items in your notes and clarify anything that seems confusing. Perhaps the observations left you with some questions: if so, write them down.

4. Complete the Observation Debrief – Engagements page

Complete as far as possible of the **Engagements** page. Be as specific as possible in giving specific examples, and noting how the exhibit facilitated these engagements. With time, you'll develop your own criteria for rating the engagements, and that's fine. The ratings are designed to get you thinking, rather than to "measure and compare" engagements between exhibits. However, do try to be consistent in your ratings.

5. Complete the Observation Debrief – Analysis (cont.) page

You are trying to analyze and make meaning of the observation. This is both art and science. Try to look at what went on from a variety of perspectives

- What did you find out that you didn't know before?
- Did the observation raise any new questions?
- What about the exhibit seems to be working well, and why?
- What doesn't seem to work so well?
- What did you learn that you can apply to the new exhibition?

Feel free to write up additional analysis on the back of any of the sheets. Do this all BEFORE your next observation.



BioMedTech Observation Protocol – Field Notes

Date: _____ Obs # _____ Initials: _____							
Entry Time: _____ AM/PM Exit Time: _____ AM/PM							
<p>Group Type</p> <table style="width: 100%; border: none;"> <tr> <td style="width: 50%;">1 alone</td> <td style="width: 50%;">4 tour group</td> </tr> <tr> <td>2 two adults</td> <td>5 adults with children</td> </tr> <tr> <td>3 several adults</td> <td>6 camp/school group</td> </tr> </table> <p>Group Size / Ages:</p>	1 alone	4 tour group	2 two adults	5 adults with children	3 several adults	6 camp/school group	<p>Race/Ethnicity</p> <ol style="list-style-type: none"> 1 African-American 2 Asian 3 Caucasian 4 Hispanic 5 Other (be as specific as possible) <p>Crowding</p> <ol style="list-style-type: none"> 1 = Empty Gallery 2 = A few folks roaming around 3 = Moderate Crowd. Short wait at popular exhibits 4 = A few more crowded exhibits, longer waits 5 = Severe Crowd. Too congested. Lots of waiting.
1 alone	4 tour group						
2 two adults	5 adults with children						
3 several adults	6 camp/school group						

Why did you select this respondent?

Are these observations of visitors in the exhibition or at an individual exhibit?

NOTES: (add more on the back if necessary)



Observation Debrief – ENGAGEMENTS **Date:** _____ **Obs #** _____

For each item, rate the overall quality of the group’s engagement on a scale of 0 to 4 (4 highest level, 0 is no engagement). Explain why you gave that rating, give specific examples, and note how the exhibit facilitated these engagements.

Physical Engagements: 4 3 2 1 0

Intellectual Engagements: 4 3 2 1 0

Social Engagements: 4 3 2 1 0

Emotional Engagements: 4 3 2 1 0



APPENDIX D: VISITOR INTERVIEW PROTOCOL

Example of Interview Protocol for the Medical Technology Exhibit (Second Site Visit)

- **Introduce myself, recruit, and get permission to tape**
 - I'm helping the Science Center make plans for new exhibits about these topics.
 - We're trying to find out what people already know about some topics, so we can make a better exhibit.
 - The interview is completely confidential—I won't even ask for your name.
 - I don't work for the Science Center, so you can't hurt my feelings when you are talking about the exhibits.

- When I use the term “biomedical technology,” what does that bring to mind? What if I use the term “medical technology”? Does that seem easier for people/kids to understand? What if we just talked about “medicine”?

- Does biotechnology help doctors deal with any of the following problems? [follow up with how, or why or why not]
 - Cancer
 - Heart disease
 - Avian flu
 - Paralysis
 - Bioterrorism
 - Malaria

- What comes to mind when you hear “Case Western Reserve University”? Do you know where it is? What kinds of things do they study there? [probe about medicine, etc.] Does that strike you as a place where they would do biomedical technology?

- Here are some words we might use in the exhibit. Please tell me if they seem appropriate for an exhibit about developing new biomedical technologies.
 - Clinician
 - Researcher
 - Investigator
 - MD
 - PhD

- Which medical devices in the exhibit would most likely include computers as important parts? Would you be interested in learning about where computers fit into medical technologies today?

- Have you ever heard the term “personalized medicine”? If so, what does the term mean to you? What would a doctor need to know about you to practice personalized medicine?



How would you feel if your doctor personalized medicine based on the race of her patients?

- Have you ever heard about “stem cells”? What can you tell me about them? Can you think of some ways they are used in medicine today? Is that something you would like to learn more about from an exhibit?
- Do people have electricity inside their bodies? What do you think it does—how does your body use it?
- Have you heard about cloning? What can you tell me about how that works? Can you think of some ways cloning is used in medicine today? Is that something you would like to learn more about from an exhibit?
- [Beside video of FES]: I noticed you did/did not watch the video. What attracted you/helped you decide not to watch it? Is this something you like to see at the Science Center? Why, or why not?
- **Closing**
 - Do you have any questions for me?
 - Thanks for your time—from me, and from the Science Center.
 - Here’s a small gift from the Great Lakes Science Center.



APPENDIX E: STAFF INTERVIEW PROTOCOL

Protocol for Interviewing GLSC Staff for the *Biomedical Technology Exhibition Project* Selinda Research Associates, Inc.

Reminder to interviewer: Try to keep within the topical framework, but don't be limited by it.

- Introduce yourself (what you're doing, why it's important to talk to them, etc.; explain that you're an independent consultant).
- Interview will take 30-45 minutes or so.
- Explain process (no right or wrong answers, confidentiality).
- Ask their permission to tape record.
- Ask if they have any questions before getting started.

Possible introductory questions:

- Please tell me about your current job and job title.
- How did you get into the field?
- I'm curious about your background. What kind of training did you get at GLSC and elsewhere?

Main interview questions:

- Please tell me about any programs and activities that you've done with visitors in the current *Medical Technology* exhibition.
- Please tell me about any other places where you have interacted with visitors about medical or human body-related topics [e.g., *Body Worlds*, *Grossology*].
- What are some effective ways of working with visitors in those settings? What sorts of activities seem to work best?
- How effective does the current *Medical Technology* exhibition seem to be? Why do you think it's effective/not effective? Have you ever observed or talked with visitors as they used the interactives in this exhibition? How do these interactives compare with the ones elsewhere in GLSC?
- How do visitors seem to react to things like human body parts and internal organs, either real/preserved, images, or simulated? What do you think we can get away with in an unstaffed exhibition?
- How do you talk with visitors about medical topics—especially young ones? How do you deal with technical terms and difficult concepts? What advice might you have for people who will write the labels for the new exhibition?
- Have you ever talked with young visitors about careers in science or medicine? Do they seem interested? Is it something they bring up themselves?
- Do you ever talk with visitors about current scientific research—about the process of doing science? Can you give me some examples? What advice might you have for people who make exhibits about current research for the new exhibition?



- Do you ever talk with visitors about controversial topics? Can you give me some examples? What advice might you have for people who make exhibits about controversial topics for the new exhibition?

Closing:

- Is there anything else you want to tell me?
- Do you have any questions for me?
- Thanks so much for your time!



APPENDIX F: DESCRIPTIONS OF THE RESPONDENTS

Visitors

Site Visit 1: Observations/Interviews in the *Medical Technology* Exhibition

Date	#	DC	Total	AF	AM	CF	CM	R/E	Type	Exhibits
3-24	1	EG	4	1	1	2		W	Obl	E
3-24	2	EG	3	1	1		1	W	Ob	W, S
3-24	3	EG	1	1				B	Obl	MI
3-24	4	EG	3	3				W	Obl	CP, G, P
3-24	5	EG	2	1			1	W	Ob	F
3-24	6	EG	4	2			2	W	Obl	P, E, MRI
3-24	7	EG	2	2				W	Obl	E, Mic, G, MRI
3-25	1	EG	2		1		1	W	Ob	MI, P
3-25	2	EG	1			1		W	Ob	CC
3-25	3	EG	2	1			1	W	Obl	E, MRI, U, DF, G, DNA
3-25	4	EG	3	1	1		1	W	Obl	P, DNA
3-25	5	EG	5	2	2		1	A	Ob	MI, P
3-25	6	EG	2	1	1			W	Obl	MRI
3-25	7	EG	1	1				W	Obl	CC
3-25	8	EG	2		1		1	W	Obl	DNA
3-25	9	EG	2	1	1			L/W	Obl	CC/MI
3-25	10	EG	3		1	2		W	Obl	F, H, S
3-25	11	EG	1	1				W	Obl	P, DNA
3-25	12	EG	2		1	1		W	Obl	G, DF
3-25	13	KZ	3	1	1		1	W	Ob	MI
3-25	14	KZ	4	1	1	2		W	Ob	MI
3-25	15	KZ	5		2	(3 children)		B	Ob	MI, MRI, U, G, W
3-25	16	KZ	5	2	1	(2 children)		W	Obl	E
3-25	17	KZ	3	1	1		1	W	Obl	E, DNA
TOTALS:	24		65	24	17	8+	11+			

Site Visit 2: Observations/Interviews in the *Medical Technology* Exhibition

Date	#	DC	Total	AF	AM	CF	CM	R/E	Type	Exhibits
5-6	1	EG	1	1				W	I	(many)
5-6	2	EG	2	1	1			W	I	(several)
5-6	3	EG	3	1	1	1		W	I	(several)
5-6	4	EG	2	1	1			W	I	(several)
5-6	5	EG	4	1	1	2		W	I	(several)
5-6	6	EG	5	1	1	3		W	I	DF +



5-6	7	EG	4	1		1	2	WWW/A	I	(several)
5-6	8	EG	5	1	3			AAA/W	I	(several)
5-6	9	EG	2	1	1			W	I	(several)
5-7	1	EG	4	1	1		2	W	I	(several)
5-7	2	EG	2	1	1			W	I	(several)
5-7	3	EG	1		1			W	I	(several)
5-7	4	EG	2	1	1			A/W	I	(several)
5-7	5	EG	2	1			1	W	I	(several)
5-7	6	EG	2	1		1		W/L	I	(several)
5-7	7	EG	3	1			2	W	I	(several)
5-7	8	EG	3	1			2	W	I	(several)
TOTALS:	17		47	16	13	8	9			

Additional Observations/Interviews in the *Medical Technology* Exhibit by K. Ziff:

Date	#	DC	Total	AF	AM	CF	CM	R/E	Type	Exhibits
4-14	01	KZ	4	1	1	(2 teens)		W/B	Obl	E, U, DF, S
4-14	02	KZ	4	1		1	2	B	Ob	E, Mic
4-14	03	KZ	4	2		2		W	Obl	(most)
4-14	04	KZ	4		1		3	W	Ob	E
4-14	05	KZ	1	1				W	Obl	E
4-21	01	KZ	1	1				W	Obl	F
4-21	02	KZ	4	1		3		B	Ob	E
4-21	03	KZ	1	1				W	Obl	MRI
4-21	04	KZ	2	2				W	Obl	F
TOTALS:	9		25	10	2	6+	5+			

KEY

Date = MM/DD

= Interview number

DC = Date collector Initials (EG = Eric Gyllenhaal, KZ = Katherine Ziff)

Total = Total number in group

AF = Number of adult females in group

AM = Number of adult males in group

CF = Number of female children in group

CM = Number of male children in group

R/E = Race/ethnicity

B = Black

A = Asian

W = White

L = Latino

Type = Type observation or interview

Ob = Observation only

Obl = Observation and Intercept Interview

I = Interview only



Time = Approx. time in the exhibit area, in minutes

Exhibits = Exhibits that we observed them using

MI = Medical Imaging

P = Prosthetics

MRI = Magnetic Resonance Imaging

E = Endoscope

Mic = Microscopes

U = Ultrasound

F = FES

H = Heart Pumps

DNA = DNA zoom and spiral

DF = DNA fingerprinting

CP = Chromosome posters

G = Genetics wall

CC = Career computers

–

W = Wheelchairs

S = Sports

GLSC Staff Interviewed

Dennis Fisher

Visitor Experience Specialist

Doug Kusak

Visitor Experience Specialist



APPENDIX G: SUMMARIES OF FINDINGS FOR INDIVIDUAL EXHIBITS

This appendix is available as a separate document entitled
BiomedicalTechnologyFinalReportAppendixG.pdf .



APPENDIX H: BIBLIOGRAPHY OF RESEARCH ON PUBLIC UNDERSTANDING OF, AND ATTITUDES ABOUT, GENETICS AND RELATED TOPICS

As they become available, additional references and sources will be posted on:

<http://www.museumdeveloper.net/understanding/underbiogenetics.htm>

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Wong, J., & Ma, J. (2004). *Giant chromosomes demonstration. Imaging Station – formative evaluation*. Unpublished manuscript, Exploratorium, San Francisco, CA. Downloaded June 19, 2006, from:

http://www.exploratorium.edu/partner/pdf/new_pdfs/giantXsomes_wb_03.pdf

Additional on-line bibliographies and sources:

The Centre for Studies in Science and Mathematics Education (CSSME) at University of Leeds. Bibliography on young people's understanding of, and attitudes to, 'the new genetics':

<http://www.education.leeds.ac.uk/research/cssme/projects.php?project=58&page=2>

People Science & Policy web site: <http://www.peoplescienceandpolicy.com/>

North West Genetics Knowledge Park (nowgen):

<http://www.nowgen.org.uk/page/index.php?sid=3>

