Creating an Informal Engineering Education Experience: Interactive Manufacturing Exhibit

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Abstract *– In the modern, technology -driven society a gap between technology use, driven by its accessibility and convenience, and technology understanding, needed for informed decision making either at the individual consumer or society level, is steadily growing. T his knowledge gap creates a need to educate general public about issues in technology and engineering, in particular manufacturing, which is the backbone of a strong economy. The formal, pre -college education however, offers very limited choices in this re spect. Use of informal education channels, such as exhibits at science museums, offers broad outreach to people of all ages and backgrounds interested in learning. The particular target audience are contemporary American youths (middle - and high school - age), who are known to be avid consumers of manufactured goods, but who most likely hold no concept of how these products came to exist or how they were made. Targeting such an audience also offers a potential of sparking a future interest in manufacturing c areer paths. This paper describes an effort carried out at the NSF Engineering Research Center for Reconfigurable Manufacturing Systems (ERC/RMS) at the University of Michigan to design, develop, and test a museum exhibit offering a visitor -centered inform al education experience highlighting the principles of modern manufacturing. The exhibit architecture is based on three principal engineering activities involved in creating consumer products: product design, manufacturing (transformation process), and mar keting and business. The exhibit attempts to explain how these fields interrelate in order to develop manufactured on an example of a well understood product – customizable pen. Each of these activities is implemented via of two complementary components: a n interactive computer game and a physical display environment. This paper discusses the conceptual design of the exhibit, and details the approaches deployed for content translation and presentation. Results from a preliminary assessment study, focused on the reception of the exhibit in a museum setting and its potential educational impact are also presented.*

Index Terms *– Manufacturing education, informal learning, educational outreach, museum exhibit design, educational software.*

INTRODUCTION

Dependency of modern societies on technology steadily grows and even accelerates, yet society-wide understanding of technology (needed for informed and critical decision-making) is usually lacking. About 70 percent of Americans are past the school age and for them to update their technological literacy requires access to opportunities outside of formal education. Younger generations have yet to develop their technological skills and interests, yet structured, pre-college education offers limited opportunities for that. The importance of inducing technological literacy and interests in youth cannot be overstated, as it affects also future supply of engineers and scientists.

Contemporary American youths are avid consumers of manufactured products. They are very familiar with a wide variety of available consumer products due to the efforts of marketing campaigns, advertising media and their own use of the Internet. However, as they buy and use today's products, they most likely hold no concept of how these products came to exist or how they were made. Overall, general public's knowledge of manufacturing is relatively limited; also its perception is really outdated (usually stuck in mass production concepts) and unappealing. This lack of knowledge creates a demotivational barrier preventing many potential students from entering the field. Such a knowledge gap creates an opportunity to educate the general public about what constitutes modern manufacturing.

An exemplary effort to bridge the technological literacy gap is currently under way at the NSF Engineering Research Center for Reconfigurable Manufacturing Systems (ERC/RMS) at the University of Michigan. To extend its educational reach to the non-university population, the ERC/RMS has invested in designing and developing a museum exhibit that offers a visitor-centered informal learning experience highlighting the principles of modern manufacturing. This paper discusses the

conceptual design and development of the exhibit and presents approaches deployed for content translation and assessment of its educational impact.

Exhibit Goals

The main purpose of the exhibit is to educate visitors about the processes in three fields crucial to industrial production – product design, manufacturing, and marketing – and how these fields interrelate in order to develop manufactured goods. . A deeper goal of the games is to introduce children, especially girls, to the types of professions found in these areas in such a way that they might later consider careers in one of the three fields [1]. For either of these goals to be attained, the proposed exhibit must accomplish three tasks: (1) **attract** visitors, (2) **motivate** them to become engaged with the exhibit, and (3) **facilitate** the acquisition of the knowledge, understanding, and attitudes the exhibit is designed to convey.

Exhibit Overview

The exhibit station consists of two main components: a set of interactive computer games and an exhibit kiosk, which constitutes both the physical display environment and a housing for the computer equipment. These parts are designed in order to satisfy the three tasks of exhibit design, mentioned above, in a complementary manner. The physical display environment is developed to attract the visitors and contribute to the facilitation of the knowledge acquisition by presenting content materials and graphic instructions for the game. The game software has the responsibility of motivating the visitor to engage with the exhibit, and it is also the component of the exhibit where the majority of knowledge acquisition will be facilitated. The exhibit is intended to be placed in participatory informal learning institutions like science centers, and as such was designed to target the majority demographic of those institutions, children of the ages 6 – 12 [2]. For this reason, when the terms "visitor" or "user" are employed later on in this text, they should be interpreted as a reference to a member of this target population.

FIGURE 1
OVERALL VIEW OF THE "DESIGN STATION" EXHIBIT INSTALLED AT THE ANN ARBOR HANDS-ON MUSEUM

The kiosk design, providing an external environment in support of the gaming software, is essential to help guarantee the involvement of visitors with the software content, but it also provides background information. To stand out in a museum environment and create an attraction point competing with other exhibits, the kiosk design has an appearance directly related to the software content. The physical form of the kiosk is derived from everyday objects (e.g., a mug containing pens and

rulers in it). The distinctive appearance creates a visual focus by leveraging these objects in exaggerated scale and bright colors. Additional board space is filled with background materials, complementing the contents of the games.

The gaming software was developed with the aim to appeal to the target audience and its content takes into account such audience members' perspectives and levels of understanding. Selected processes found in product design, manufacturing, and marketing are presented by interactively leading the user through the development cycle of an example product, specifically, a customizable pen. The selection of a pen as an exemplary product was deliberate: because it is a simple and ubiquitous product, it is well understood, and yet it enables the presentation of more complex concepts related to its design and manufacture. The interactive tasks that the user is asked to complete are simplified versions of tasks found in the real-world professions represented by the games, or tasks that encapsulate some of the ongoing concerns of professionals in that field.

The three games intended for this exhibit, *Design Station*, *Some Assembly Required*, and *Business as Usual* , have environments set in the offices of a design firm, the floor of a manufacturing plant, and a marketing office, respectively. Each of the games follows a common structure: the player is greeted by an avatar representing an employee of the environment, who introduces the setting and explains in general the type of work that is engaged in that environment. The host avatar then explains to the user that the host will need the player's help in completing a task in the environment, and explains how the task is to be executed.

Upon completion of the in-game tasks, the user's performance is rated and he or she is given detailed feedback about the basis for his or her score. An assessment of the user's comprehension of concepts and terminology presented in the exhibit is incorporated into the game under the guise of a bonus quiz. Unbeknownst to the user, the game is anonymously recording his or her in-game actions for later analysis to aid in the assessment of the exhibit.

THE DEVELOPMENT PROCESS

Development strategies for the Design Game exhibit kiosk involved a number of short and long term goals. Short term goals included installing a physical mock-up for initial usability assessments, defining design guidelines, and the refinement of strategies for long-term development. This implementation process has been applied to both the software and physical exhibit development, which were carried out in parallel.

The early stages of the physical design mock-up were to explore the best ways of satisfying basic functions: holding the computer screen securely and determining if children can reach the screen. Initially, the computer screen was simply installed into a drafting table adjusted to an appropriate angle for the best accessibility. One reason a drafting table was used was to demonstrate the design activity which usually takes place in design studio. It was initially thought that tools of the trade, like rulers, compasses, and French curves, could be mounted on the table surface, but safety and durability concerns precluded this. This mock-up demonstrated the need for a more efficiently designed environment for the accessibility of both individuals and groups, and a more attractive and appealing organization of the exhibition objects.

This trial was followed with the development of a more extensive approach to designing the exhibit kiosk and incorporating components such as text, graphic materials, interest-attracting objects, and the game play screen. In this approach, the target was to develop a design solution which incorporates long-term goals with an inexpensive and modifiable manner. In accordance with the main objectives of the project, displaying the theme with an interactive game, the components had to fulfill the basic requirements of housing the computer screen securely, narrate the basic idea of the game, and give the instructions of how to play.

The evolution process of the exhibit was carried out parallel in software and physical design development. On the software development process side, the first step was the creation of a Microsoft Power Point presentation which made use of some interactive functions of this application to illustrate potential functionality. The second step was to implement the game within a web page by using Java script. This step was intended to provide web access to the game for user trials. The last step was to implement the fully functional game using Macromedia Director, which enabled the coders and graphic artists to more seamlessly work together to create a game by integrating interactive interfaces with graphic design. Prior to installation in the museum, the final game was tested by users selected from different age groups. For the other side, the evolution of the physical exhibition components, the first step was conducted by revising the long terms goals and applying them to the design process in brainstorming sessions held by the project team. Finding an optimal solution to the competing needs of the long term goals, like developing an exhibition fit for traveling to different museum settings, as well as the enduring need for an interest-capturing display required the development of a set of firm criteria to underlie the design. A set of criteria emerged from the brainstorming and research process of the project team, whose varied perspectives and fields of specialization greatly contributed to the process. Then, the next step was to suggest design schemes that would fit these criteria best, again through a brainstorming session. Some of these schemes were reproduced as scaled physical mock-ups, and ranked on the basis of their interpreted performance for fulfilling the criteria. As a result of this assessment, the design schemes ranked first in the physical mock-up lineup established the main features of the exhibit design that would be built for the Design Station. Much like the software development, the physical exhibit was constructed through an iterative testing and

assessment process, where competing construction techniques were tested and the most usable solutions were applied to the actual exhibit. After a year of parallel development, the exhibit kiosk and the game software reached completion and were installed in the Ann Arbor Hands-On Museum, (Ann Arbor, Michigan) in July 2004.

The project has been carried out as a partnership effort between ERC/RMS and the Ann Arbor Hands-On Museum (AAHoM). AAHoM is an 20-year old institution with over 200 hands-on exhibits on display. The museum accomodates over 190,000 visitors a year and is also a member of the Traveling Exhibits At Museum of Science (TEAMS) Collaborative which facilitates sharing of exhibits between member museums. The Manufacturing Exhibit is being developed as modular and portable, so it can become part of this exchange program.

IMPLEMENTATION

To better illustrate how the games implement the chosen educational and presentational strategies, a case study of the first completed game, the *Design Station* kiosk, is interleaved with descriptions of the theories underlying the design decisions that led to its creation. Although the content of the other two kiosks are different, many of the same instructional and presentational techniques apply. We are dividing the discussion into three functional categories. The first is devoted to the task of attracting visitors to the exhibit, which is largely a function of the physical exhibit design. The second category addresses the strategies used to motivate visitors to engage with the exhibit, which by virtue of the exhibit focus are mostly implemented via software design decisions. The third function of the exhibit, to facilitate the learning of the visitors engaged with the exhibit, is accomplished by both the software and physical exhibit designs.

Attracting Visitors: Problem Definition

One crucial step in implementing the exhibit project is bringing the exhibit into display in a museum environment in order to provide visitor/ target audience with a physical contact with the exhibition content.

Children's science museums have an educative role in new generations' science education [3]. This value comes with the potential of the science museums in transmitting the scientific knowledge to young generations. This potential lies in the exhibitions that represent themes from science and technology fields in temporary or permanent displays. These exhibitions consist of free-standing individual or grouped exhibition kiosks that convey the themes to visitors in an educative and entertaining manner. This manner provides children with an informal learning environment which is characterized by free-choice on the part of the visitors and by having the properties of being unstructured, non-sequential, self-paced, voluntary and exploratory, as well as being non-assessed, open-ended and social [4].

The role of informal learning environments, particularly museums with interactive science exhibitions, has been argued in contemporary theories of education. The constructivist theories of learning suggest that informal learning allows a more incremental development of concepts in human mind. This development occurs with an active involvement with the knowledge source, which is an alternative to passive learning. Interactive science exhibitions are suggested as one source that appeals to and motivates children to learn with active involvement and interaction.

In order to achieve the requirements of informal learning, the exhibition element must be designed for presenting knowledge in an appealing form to the visitors. Interactive exhibition kiosks are usually installed in the museum within an 'open plan' of organization, or within a vague circulation order, provided that the exhibition kiosk is a part of thematic array of a temporary exhibition. In the museums with open plan organizations, bringing visitors together with a particular exhibition may be coincidental. Since open plan museums provide visitors with an unstructured sequence of viewing the exhibitions, kiosks are accessed by visitors through their free and voluntary choices. Some studies discuss the tendencies and behavioral patterns of children in museum environments on the basis of observational research. These observations note that children express an individualistic exploratory behavior. They usually first look around, go on and participate later; only few of them read the graphics and most of them work by trial and error, imitating what is done by their peers [5].

First-time visitors initially scan the museum setting to find the most interesting and appealing artifacts. Some strategies for museum layouts, such as planning for group visitor excursions by targeting certain exhibits, or purposefully-designing an exhibition kiosk, may help to eliminate this coincidental situation and, by bringing visitors into contact with materials, begin the process of facilitating knowledge acquisition. This paper focuses on discussing the strategies used in designing an exhibition in developing the ERC Museum Exhibition Design Game Kiosk. In order to guarantee visitors' involvement with the exhibition kiosk, some effective engagement strategies must be employed in the design and implementation of the kiosk. These mostly involve careful planning and designing the physical parts of the exhibit kiosk in accordance with the content.

The physical part of the exhibit kiosks may contain the representation of the content material via selected objects, graphic material and text. The overall design and composition of these parts are critical to achieve the intended communication of the content. The physical part may contribute to or, less desirably, mislead what visitor would learn from the exhibit. For this reason, an exhibit kiosk, designed for educative purposes, should reflect the content clearly to the target

audience, and the components of exhibit kiosk, such as text, graphic images, and objects, should be composed for transmitting the content clearly and correctly, without factual errors.

However, finding the most clear and appealing way of using and incorporating the components of exhibit kiosk is not easy. Therefore, the strategies of developing an exhibit kiosk for an informal learning environment involve implementing the design in an iterative and evolving process. In this manner, the first exhibit of ERC/RMS Museum Exhibit Project reached completion at the end of a process of properly understanding the design problem and exploring the ways in which the design would appeal the visitors most effectively.

Attracting Visitors: ERC/RMS Museum Exhibit Project- *Design Station* Kiosk Implementation

The ERC/RMS Museum Exhibit Kiosk consist of two main physical parts: panels that hold the game theme and instruction graphics, which stand out as an oversized "notebook", and the case housing the computer equipment and presenting the game to visitors, which stands out as a oversized "coffee mug holding pens and rulers". These parts are designed to go beyond the conventional and straightforward manner of fulfilling the basic requirements. The appearance of the "notebook" and "coffee mug holding pens and rulers" in the museum gallery reference the familiar figures of two daily use objects, yet in an odd scale and context. This appearance of the exhibit kiosk is deliberately intended to attract the view of visitors among other exhibition elements in the museum. As it has been argued in perceptual and cognitive processes, the way people show an interest in some environmental information involves the process of recalling familiar images stored in internal representations in the mind. It has also been argued that too much familiarity create a monotonous effect and does not stimulate the attention [6]. For this purpose, the cylindrical case that holds the computer screen and equipment was designed and built as a blue coffee mug, with objects like pens and rulers with bright colors attached to it. Thus, the odd scale of familiar objects positioned in the museum context along with the use of bright colors are strategically planned in the design scheme in order to direct visitor attention and interest to the exhibit kiosk, which can be seen as the first step of facilitating knowledge acquisition.

FIGURE 2
A VIEW OF THE "DESIGN STATION" EXHIBIT SHOWING THE ORGANIZATION OF GRAPHICS AND TEXT MATERIAL ON THE "NOTEBOOK".

In addition, the "notebook" and the "coffee mug with pens" recall the products that come into existence as a result of engineering design and manufacturing processes, which is conveyed in the *Design Game* . This also provides a necessary connection in children's mind between consumer products and processes that bring these products into existence. It has been suggested that this design extends the straightforward appearance of an interactive exhibit accessible by only a computer screen and a mouse on a table. The screen is embedded into the "coffee mug," and the game can be played just by touching the screen [7]. Moreover, the cylindrical shape of the coffee mug allows visitor to have a collaborative experience with their

parents and friends. Initial observations show that up to four people can have a visual contact with the game at the same time. The height of the coffee mug and therefore the vertical position of the computer screen enables access by not only by children but also adults and handicapped persons.

Some of the previous research on exhibition types and their components proved a connection between knowledge acquisition and the ways in which exhibit types and their components are organized. The results show that exhibitions which encourage more participatory engagement from visitors and which involve a greater number of senses in this engagement, through components like real objects and sound, are more effective in transmitting knowledge. These studies classify the exhibition components from the most "abstract" and the most "concrete", and define an exhibit with only text on flat panel as the most abstract, whereas an exhibit with objects, visual materials, representations of reality, and interfaces allowing sensory involvement are defined as the most concrete. The results proved that a concrete exhibition has the most significant effect on knowledge gain [7]. In this context, the ERC/RMS Museum Exhibit Project – *Design Station* kiosk can be recognized as having well-defined features. In addition, the layout of the graphical material located on the "notebook pages," presents the game theme and instructions precisely. For this purpose, text and the graphics are organized in information chunks. Cognitive theories suggest that that human mind has the ability to most efficiently process information organized into 3-5 information chunks [6]. The question of how the *Design Station* exhibit kiosk attempts to accomplish the other two tasks needed for transmitting knowledge, to motivate users to engage with the exhibit and to facilitate an understanding of the presented material, will be discussed below, along with how success at these tasks will be assessed.

Motivating Visitors: Problem Statement

The purpose for motivating visitors to interact with the exhibit is relatively straightforward: previous research has shown that the longer a visitor interacts with an exhibit, the greater the possibility that learning has been facilitated [8]. In a free-choice learning environment like a science center, an exhibit must compete visually, aurally, and kinetically with the other stimuli present in the museum, so the design of the visual, aural, and interactive components must be engineered to be compelling enough to hold a visitor's attention [5].

FIGURE 3
A SERIES OF INITIAL SCREENSHOTS FROM THE INTRODUCTION TO *DESIGN STATION*.

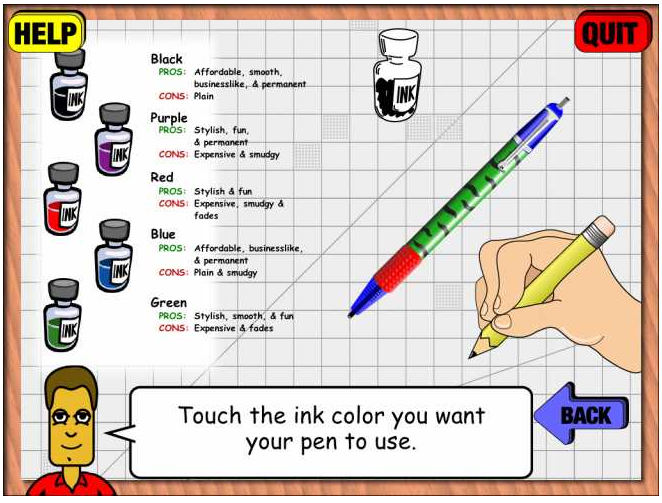
Motivating Visitors: Role-playing and Narrative

The power of narrative, first-person stories to engage visitor interest in a museum exhibit has long been acknowledged in museological research [9, 10]. To capitalize on this, each game begins with an on-screen character greeting the player and introducing him or her to the setting, story, and goals of the game (see Figure 3). The player is then invited to act out the story that has been introduced. In the case of *Design Station* , an employee of a design firm invites the user to help him conduct market research and then to help his firm design pens that are likely to be a market hit (and sell well). By conducting this market research, the user discovers what qualities (such as affordability, durability, styling, etc.) would positively or negatively affect the buying decisions of the target market. The design process is somewhat abstracted from what would occur in real life, in that a user chooses from pre-established options for the tips, grips, bodies, caps, and inks to be used in the pen design. Each of the pen parts has distinct attributes that either match or conflict with the qualities the market research subjects requested, allowing for 1,953,125 different pen designs, and the user must engage in the nontrivial task of selecting the parts that would best reflect the desires of the target market. By placing the user in a goal-based "embodied story", or a narrative where the visitor is interactively playing the central role, the intent is to motivate and engage the visitor and to encourage a lengthier involvement in the game [11].

FIGURE 4
A SCENE FROM THE MARKET RESEARCH PORTION OF "DESIGN STATION", DEPICTING AN INTERVIEW WITH A MALL DENIZEN.

Another strategy to lengthen the time a visitor will tarry is drawn from current theories on the impact of affect. Attractive, well-designed interfaces/environments have a positive effect on a person's emotions, and in turn these affective qualities impact a person's performance with that interface/environment, increasing the amount of time that they are likely to pursue a task that is difficult [12]. By providing an interface that is brightly colored, largely pictorial, and cartoon-styled, we hope visitors will be encouraged to linger and explore the game (see Figures 3 -8) [13].

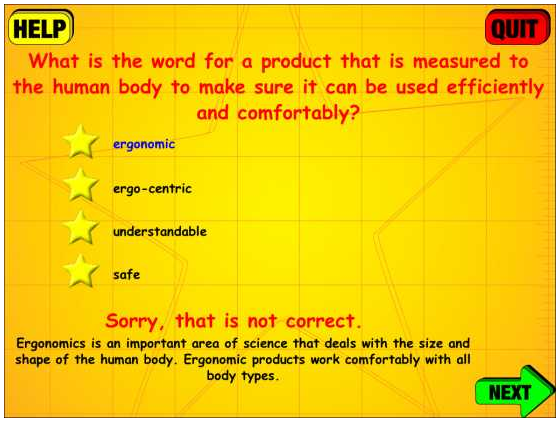
FIGURE 5
A SCENE FROM THE PEN DESIGN PORTION OF "DESIGN STATION", DEPICTING THE SELECTION OF AN INK COLOR. EACH TYPE OF INK HAS PROPERTIES SUCH AS AFFORDABILITY, STYLISHNESS, SMUDGINESS, ETC., THAT EITHER DO OR DO NOT MATCH UP WITH THE STATED PREFERENCES OF THE PEOPLE INTERVIEWED AT THE MALL. THE TASK OF THE USER IN TH EPEN DESIGN PORTION OF THE GAME IS TO CHOOSE PARTS FOR EACH PEN (THE PEN TIP, GRIP, BODY, CAP, AND INK) THAT BEST FIT THESE PREFERENCES.



Special attention must be given towards implementing strategies to motivate the participation of girls, because girls are anecdotally less likely to become engaged by technology-heavy science center exhibits [1, 5]. Children are documented as being able to recognize early on which computer games are "intended" for boys, and which are "intended" for girls, judgments that are largely made on the basis of the artistic and color schemes used [14]. In addition to initial impressions, some of the documented reticence girls have towards computer games is a result of the structure of the games themselves; there is some evidence that girls tend to prefer games that require cognitive skills that girls naturally possess, like matching, memory, and verbal skills, and that they prefer games that center on creation rather than destruction [14, 15]. Even the means

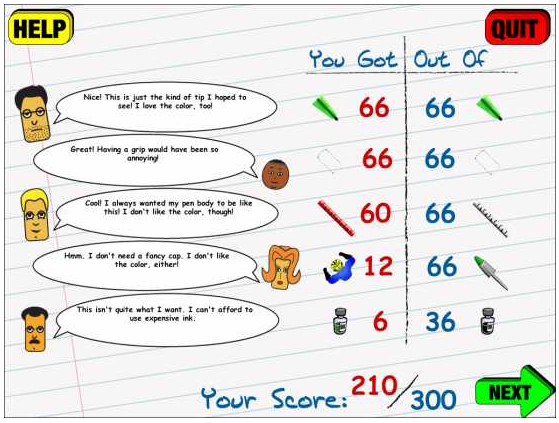
provided for playing the game can introduce bias: girls seem to have more problems with certain input devices – although females show equal performance to males with kinesthetic input devices like touchscreens, they perform markedly worse with an abstracted input device like a mouse [16].

FIGURE 6
A QUESTION FROM THE IN-GAME BONUS QUIZ. THE QUESTION READS: "WHAT IS THE WORD FOR A PRODUCT THAT IS MEASURED TO THE HUMAN BODY TOMAKE SURE TI CAN BE USED EFFICIENTLY AND COMFORTABLY?" IN THIS SCREENSHOT, THE USER CHOSE THE WRONG ANSWER, TRIGGERING THE GAME TO HIGHLIGHT THE CORRECT CHOICE ("ERGONOMIC") AND PROVIDE A DETAILED EXPLANATION: "SORRY, THAT IS NOT CORRECT. ERGONOMICS IS AN IMPORTANT AREA OF SCIENCE THAT DEALS WITH THE SIZE AND SHAPE OF THE HUMANBODY. ERGONOMIC PRODUCTS WORK COMFORTABLY WITH ALL BODY TYPES."



We have made an effort to design our games to appeal equally well to both genders. To counter immediate impressions, we have been careful to stay away from using graphic styles that skew towards any obvious gender stereotypes, using neutral and primary colors in cartoon representations that are neither too metallic and intimidating nor overly pastel and precious (see Figures 3 - 8). In the *Design Station* , the in-game goal is to listen to the expressed needs of potential consumers and design a pen based on those needs. This task requires the user to read the comments of potential consumers, remember their preferences, and to later select pen components that meet best the majority of these preferences (see Figures 4 - 5). Task performance thus depends on the verbal, matching, and memory abilities of the user, to better enfranchise female players. We also make use of a touchscreen interface instead of a traditional pointing device to level the input "playing field" (see Figures 1 - 2).

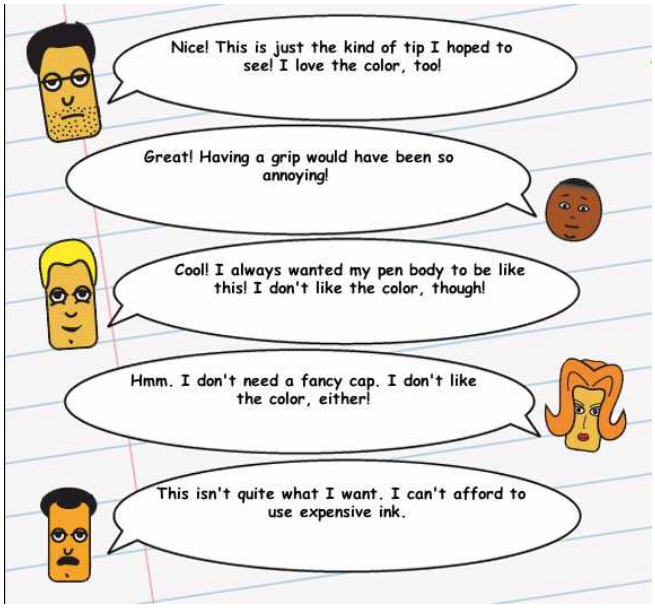
FIGURE 7
A SCREENSHOT OF THE SCORE SCREEN, AFTER THE USER HAS CONDUCTED MARKET RESEARCH INTERVIEWS AND DESIGNED A PEN TO MEET THE MARKET'S DESIRES. THE CHARACTER HEADS REPRESENT INTERVIEWEES, WHO ARE COMMENTING ON THE DEGREE TO WHICH A CHOSEN PEN PART MEETS THEIR NEEDS. THE LEFT COLUMN OF SHOWS WHAT PARTS THE USER SELECTED FOR THE PEN TIP, GRIP, BODY, CAP, AND INK. THE RED COLUMN OF NUMBERS DENOTES THE SCORE AWARDED FOR EACH OF THESE CHOICES. THE SCORING FOR EACH PART IS DEPENDENT ON MATCHING THE LARGEST NUMBER OF POSITIVE, OR "PRO" QUALITIES, REQUESTED BY THE INTERVIEWEES, AND AVOIDING THE LARGEST THE NUMBER OF NEGATIVE, OR "CON" QUALITIES , THAT THE INTERVIEWEES SPECIFICALLY EXPRESSED DISTASTE FOR. THE RIGHT COLUMN SHOWS THE PEN PARTS THAT WOULD HAVE OPTIMALLY MATCHED THE INTERVIEWEES' NEEDS, AND THE POSSIBLE POINTS TO BE AWARDED.



Facilitating Learning: Problem Statement

There are 3 main types of topics that the educational games are intended to convey: factual knowledge about a career field, such as common job titles and certain key vocabulary terms, functional knowledge about a career field, such as a task or process one might go through in the field, and a rudimentary understanding of the semiotic domain important to the career field. The visitor should come away from the gaming experience with some knowledge of pertinent facts and terms, some understanding of procedural processes, and some appreciation for the relevant values of the career field. In general, we have followed constructivist, situated theories of learning to impart these types of knowledge [17, 18, 19]. In the case of *Design Station*, the intention is for the user to gain an understanding of the product development cycle, know some important universal design properties, and have an intuition for the value of engaging in market research. We especially wished to stress the notion that designing a product always involves tradeoffs, and that often attaining a good design is a matter of finding the right balance of tradeoffs.

FIGURE 8
A CLOSE-UP OF THE INTERVIEWEE COMMENTS FROM FIGURE 7. THESE COMMENTS ARE GENERATED DYNAMICALLY TO EXPLAIN WHICH CHARACTERISTICS OF THE CHOSEN PEN PARTS EITHER DO OR DO NOT MEET THE INTERVIEWEE'S NEEDS. FOR EXAMPLE, THE FIRST INTERVIEWEE FULLY APPROVES OF THE PEN TIP CHOICE, COMMENTING: "NICE! THIS IS JUST THE KIND OF TIP I HOPED TO SEE! I LOVE THE COLOR, TOO!" THE LAST INTERVIEWEE DOESN'T LIKE THE PRICE TAG OF THE CHOSEN INK, HOWEVER, SAYING: "THIS ISN'T QUITE WHAT I WANT. I CAN'T AFFORD TO USE EXPENSIVE INK."



Facilitating Learning

Some of the factual knowledge is situated in appropriate contexts within the game's story, because the use of vocabulary terms in the context of an authentic activity helps with the acquisition of those terms [18]. The bulk of the factual information, however, is presented in a different modality, namely in print on the physical display housing the game. Effort has been made to make these labels as clear and concise as possible, so that acquiring knowledge from them is as smooth a process as possible [7]. The in-game bonus quizzes, which reference this factual content, incorporate three of Gagne's instructional techniques to help users acquisition the knowledge. These quizzes provide an opportunity for the students to engage in (3) retrieval of information they should have gleaned from the game or the physical display in order to (6) respond to the quiz. Moreover, the immediate disclosure of the correct answers, with an explanation of why the answer is correct, provides (7) reinforcement (see Figure 6) [20]. If the player is accompanied by friends or family members, the presence of easily visible factual information on the physical exhibit allows the companions to aid the player in answering the bonus questions, adding a potential social dimension to aid the learning process [19].

The acquisition of functional knowledge, an understanding of how to execute a task, can be best facilitated by placing the player in a situated, goal-based scenario [21, 11, 18]. The game's goals have been designed to align with goals that are important to the career field being depicted, and the reward structure embedded within the game is designed so that the user

must construct an internal understanding of the required tasks in order to score well (see Figures 7 - 8). In *Design Station* , the user's score depends on how well they have designed a pen to meet the needs of the people they interviewed in the mall. The more people they were able to interview, the more likely it is for the user to have formed a clear picture of the needs of the target market, thus implicitly stressing the importance of thoroughly understanding a market before creating a product to be sold in it.

It is also planned that this understanding will be enhanced and reinforced by visitors' attention to the exhibit kiosk, in particular to the graphic information on the "notebook pages" of the kiosk. This graphic information is designed to summarize the topics in the game, and to outline the chunks of the information with concise text and graphic illustrations in coordination with the game.

Impacting Future Career Choices

One important role computer games can play, a role that is more difficult for other forms of media to take on, is to serve as a semiotic primer for a real-world scenario or environment. By structuring the game as a first-person role-playing experience, we support the cognitive process wherein "… being (or having been) a member of the affinity group associated with the precursor domain facilitates becoming a member of the affinity group associated with the other domain, because the values, norms, goals, or practices of the precursor group resemble in some way the other group's values, norms, goals, or practices." [22]. In other words, we hope to prime players to consider a career in the represented field by inculcating them with a primer of that field's semiotic domain, and we do so by engaging them in a task found in that domain, because "[in general] it is often easiest to explain what a domain is about to prospective members of a community by letting them complete a task in the domain." [21].

ASSESSMENT

In the first attempt at gauging the success of the exhibit, two complementary visitor study approaches were taken, an observational study, conducted by a human observer, and the passive logging of in-game visitor behaviors, recorded automatically by the game software. The specific form of the second observational approach was drawn from another study designed to capture the relative engagement levels of children visiting science center exhibits [5]. This study design was then expanded to capture and codify the social context of any observed visitor interest. The second approach, passive data logging, is somewhat akin to website "hit" data, recording which game elements the user tapped on the touchscreen monitor and at what times these elements were touched, as well as certain relevant details about the current game scenario. For a limited span of time, the game also asks the user to input his or her age and gender, so conclusions might be drawn about how different demographics respond to the game. A month after installation, the software will cease to ask for demographic information, a compromise between the need for researchers to collect data and the desire for museums to provide enjoyable, non-invasive exhibits to their visitors.

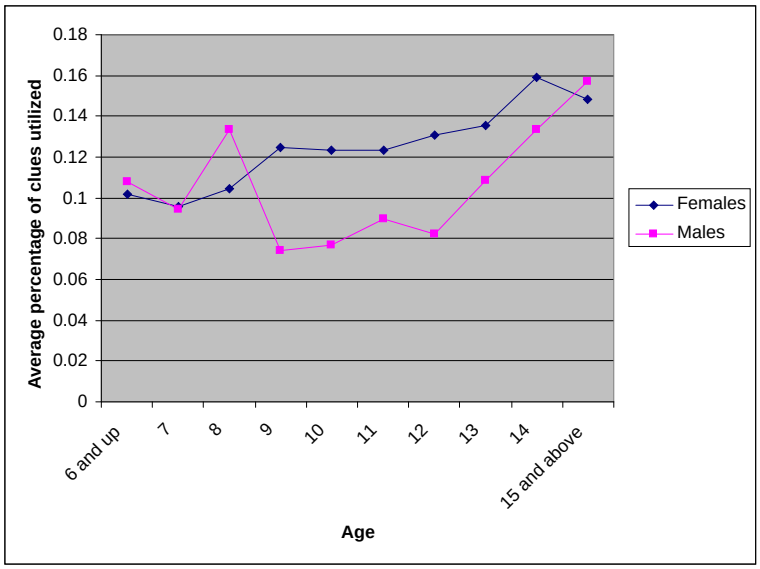
Observational study - execution

The engagement-level/social context observational study was conducted by a member of our research team, who was equipped with preprinted, pre-codified data sheets to allow the observations to be recorded in as quick, accurate, and impartial manner as possible. The observer sat inconspicuously in the area of the ERC/RMS exhibit for several hours at a stretch, and ultimately will repeat the study on several different days of the week to account for the different types of traffic the museum experiences on weekdays and weekends. On no occasion did the observer approach a visitor or engage him or her in conversation, but facial expressions and body postures could be seen and conversations between visitors could easily be overheard from where the observer sat.

To simplify the categorization of exhibited interest, three levels of engagement were established and labeled: spurious, casual, and deep, much as was done in the study in [5]. A "spurious" level of interest in an exhibit component was determined to be characterized by a fleeting degree of visual attention, if the component was largely visual, and by random, chaotic actions, if the component is interactive. A "casual" level of interest was determined to be exhibited by a lingering gaze, if the component was largely visual, and a level of interaction complaint with the accepted use of the component, but without apparent goal-oriented behavior, if the component was interactive. So, for example, to be labeled a "casual" player the user may have interacted with the game in the "intended" manner, but did not devote much attention or apparent thought to attaining a high level of performance in the game. A "deep" level of interested is marked by an extended, intent focus if the component was largely visual, and by marked goal-oriented behavior (such as verbalization of on-screen text or goals, thoughtful actions, exhibited reflection on performance) if the component was largely interactive.

Social context data was codified by assigning a unique identification number to each visitor that approached the exhibit, which was used as a reference in descriptions of social contexts. At the time a visitor joined in a new examination of or interaction with the exhibit, the ID numbers of the other visitors already present at the exhibit and the new visitor's apparent relation to them was recorded. If the new user just watched the other visitors, or took a more active role and attempted to help or coach them in their examinations or interactions with the exhibit, this fact was also noted. Additional, unplanned-for social events were recorded in the 'Notes' section of the data sheet for future codification.

FIGURE 9
A MEASURE OF THE SATISFACTION OF IN-GAME GOALS, BROKEN DOWN BY AGE AND GENDER. THE 'PERCENTAGE OF CLUES UTILIZED' MEASURES HOW MANY CLUES THE PLAYER WAS ABLE TO REMEMBER FROM THEIR MARKET RESEARCH AND MAKE USE OF IN THE PEN DESIGN STAGE OF THE GAME.



Observational study – Results

The observational data, owing to the time required for the transcription from handwritten sheets to a digital format, has not been completely analyzed, but preliminary results show that the exhibit seemed popular - more than 90% of the visitors who passed by the exhibit when it was unoccupied gave the game a try, and the majority of visitors who initially found it occupied were recorded returning to the exhibit at a later time to play. There was a fairly even split among attention levels, with about 20% of the visitors showing a spurious level of attention, 42% showing a casual level of attention, and 33% showing a deep level of interest in the exhibit. The fact that the category visitors giving the exhibit spurious levels of attention is by far the smallest is encouraging. It is also encouraging to see that these percentages hold across gender, with males and females engaging with relatively the same levels of interest. Although a complete analysis of the engagement level/social context data is still pending, the anecdotal experience of the observer was that younger children and a parent or other adult figure often engaged with the game at the same time, usually with the small child sitting on the lap of the adult, and engaged together at a higher rate than either age group engaged with the game alone. Very often the adult helped or coached the child through the game play, which shows the exhibit provides a social learning environment for families.

Automatic Data Collection - Execution

The second component to the visitor study begins with the automatic, largely implicit gathering of in-game use statistics. Akin to webpage "hit data", the game software records the user's actions within the game and the times at which they occur. Some of these statistics are as basic as recording what users touch on-screen at different points in the game, and some are as complex as an estimation of the degree to which users, in making their pen design decisions, took advantage of the clues they were exposed to when interviewing potential customers at the mall. Every time a game is exited, the statistics for that gameplay episode are saved as a time-stamped text file. The biggest advantage of this approach is that a human observer need not be present, and that data can be gathered for extended periods of time. With traditional visitor studies, time and personnel are always limiting factors. There is also the effect that "being watched" has on a visitor - inhibiting or otherwise affecting a visitor's behaviors.

FIGURE 10
A MEASURE OF THE LACK OF CORRELATION OF AGE AND GAMEPLAY DURATION, BY GENDER.

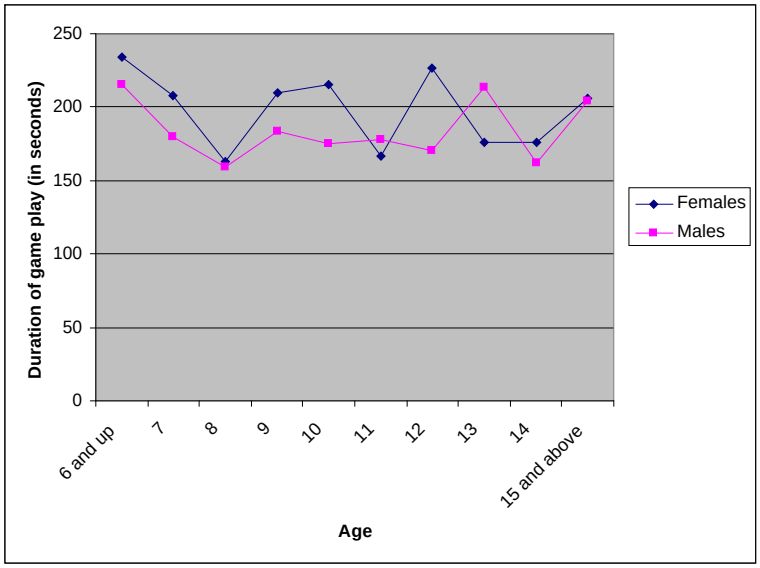
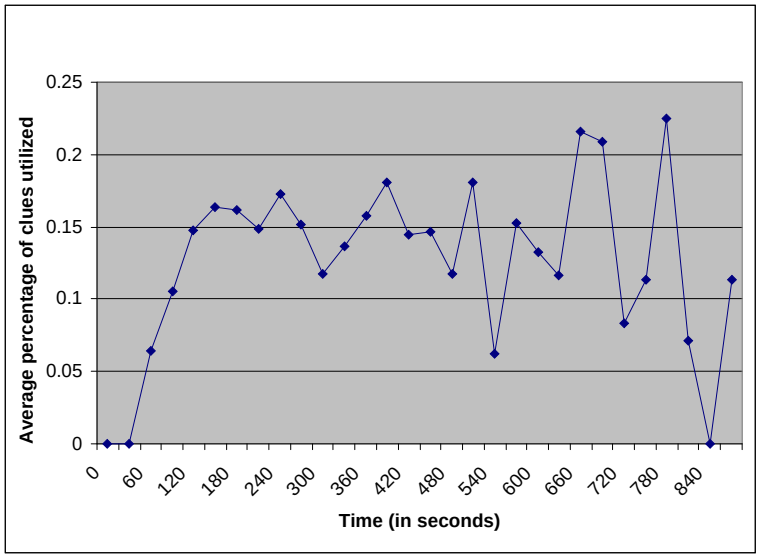


FIGURE 11
A DEPICTION OF THE LACK OF CORRELATION OF GAME PLAY DURATION AND THE NUMBER OF CLUES UTILIZED.



Automatic Data Collection - Results

Preliminary analysis of the automatically collected data indicates that the ERC/RMS exhibit has been quite a success. In a single six-day span, 897 users were recorded playing 1,068 games, with the games averaging to be about 3 minutes long. The gender ratio of these 897 players was a bit of a surprise, with a slight majority (55%) of the game players reporting their gender to be female. Given that girls have been found to be less likely to engage with technically-leaning exhibits in science centers, this is a pleasant finding. Not only are they engaging at higher rates than males, they are performing better, as shown in Figure 9. Almost regardless of age, the female game players were able to perform highly at recalling the clues they were provided in the market research segment of the game during the pen design portion of the game. One initial thought was that

perhaps the female players were spending more time playing the game, because males are more accustomed to quick-reflex game play, and perhaps the slower game play, especially among older females, led to more considered pen part choices [14].However, Figures 10-11 show that the performance trend is not dependent on the age of the players or on the duration of the interaction, so it is not a result of differing game play styles, but instead may show that we succeeded in designing the game to appeal to the cognitive abilities of female players.

SUMMARY

Conclusion

The introductory data collection in the Ann Arbor Hands-On Museum is partially completed and analyzed. The purpose of our assessment is to investigate these questions: (1) what are the levels of involvement that the visitors engage the exhibition with, and particularly which components of the kiosk attract their attention, (2) what is the percentage of fully- engaged visitors (3) using the demographic information provided by visitors, which groups show the highest level of involvement with the exhibitions. Investigating these questions will show whether the exhibit achieves the goal of attaining the interest of the visitors, and whether visitors experience the all phases of the game. In addition, this analysis is intended to describe and measure the interest to and engagement with the exhibition game by females.

All of our initial observations suggest that the exhibition has achieved its established goals. The preliminary results show that among the goals of the project, motivating the visitors to engage with the game content is attained. According to the anecdotal observations, there is a high rate of interest shown in the exhibit by visitors who walked by, showing that the task of attracting the visitors may also be fulfilled. This will be confirmed with a future observational study devoted measuring this potential of the exhibit. Measuring the degree of learning facilitation, however, hinges on refining the existing automatically collected data, so that each game play trace reflects a single user's playing experience accurately. This will be addressed by employing a more sophisticated analysis technique.

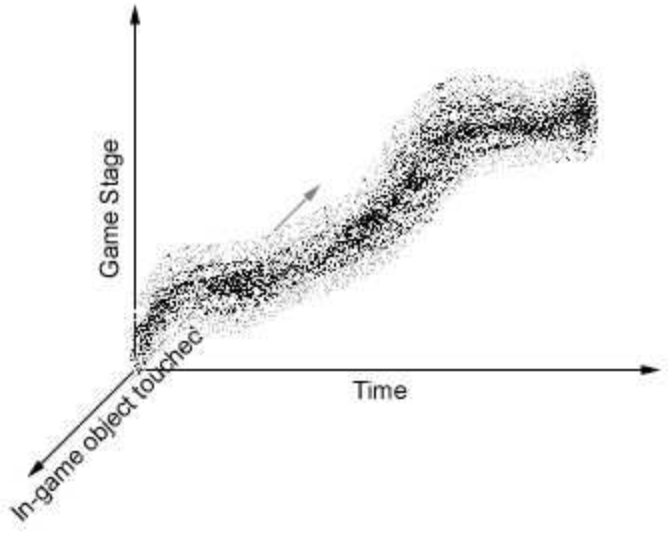
Future Work

The observational study on the potential of the exhibit in attracting the visitors will be designed to measure the effectiveness of the exhibit kiosk and its components in the museum setting. These observations aim to measure and demonstrate to what extend the exhibit kiosk achieve the goal of bringing the visitors together with the content and motivate their engagement. This observation will include counting the number of visitors who make contact with the exhibition at any level of engagement within the pool of all visitors entering the gallery that the exhibition kiosk stands in. Another task in these observations will also involve recording which components of exhibition are recognized as the most attractive and interesting for visitors. This will help to explore the effect of different components of the exhibition, such as text and graphic material, three dimensional objects, or the game itself, on visitors' involvement.

We found that the major barrier to making use of automated data collection to measure potential learning gains is in the separation of good records of discrete game-play experiences from experiences "contaminated" by multiple users. One key difference between the data collected automatically by our game system and the analogous website "hit data" is a question of the identity of the user - it is a rare occurrence where one user gives up on browsing a website, and another user takes up exactly where he or she left off, let alone a scenario where the first user gets pushed aside by the second. In the free-choice informal learning environment, however, such chaotic interplays are the norm, not the exception, complicating any detailed analysis of visitor learning gains. For this reason, we found that automated data collection probably should not stand on its own as a visitor study technique, but used in conjunction with physical observational studies and modern machine learning analysis techniques, it could be converted into a very powerful tool.

We are interested in culling these "mixed" use profiles from our analysis, and we are also interested in separating the spurious users from the casual and deep users, so that more detailed attempts at measuring learning gains can be made. Machine learning, specifically automated classification methods, can help us do this. Because a physical observer is recording behavioral and interest-level data for several observation periods, while the software is simultaneously recording its own observations, the human observer's data can be used to label the data collected by the software into categories. Imagine a data space where the x-axis is elapsed time, the y-axis is comprised of the sequential game stages, and the data points represent objects touched by the user in playing the game (see Figure 12). It is easy to suppose that a person who plays the game with intention would create a swath of points that is quite different from a person who is spuriously touching the screen, or for that matter from the swath created when one player has walked away from the game and another visitor takes over when they approach. It should be possible to generalize these intentional gameplay swaths, perhaps by using a best-fit line algorithm, and use this to determine which gameplay episodes are worthy of further study.

FIGURE 12
AN IMAGINING OF INTENTIONAL USER INTERACTIONS, WHEN PLOTTED.



Once these remaining analysis issues are resolved, we will be free to apply what we have learned to the design and implementation of the two remaining ERC/RMS museum exhibits. The next phase of development is designing the physical display for the manufacturing exhibit, and developing the software design for the business exhibit. Many of the same analysis techniques will be applied to these exhibits once they are installed in the museum, which will complement the existing design exhibit. Additionally, we will design an observational study to capture the degree to which the triumvirate exhibit teaches visitors how the three phases of product development interrelate.

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