AC 2008-1471: WE GOT GAMES: INFORMAL TECHNOLOGY EDUCATION IN A HANDS-ON MUSEUM

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Abstract

A growing gap between technology use and technology understanding in a consumer society creates a need to educate general public about manufacturing - the backbone of a strong economy. This paper describes development of a museum exhibit: a visitor-centered informal education experience highlighting the principles of modern manufacturing. The exhibit architecture reflects three principal engineering activities involved in creating consumer products: product design, manufacturing, and marketing/business. It explains how these fields interrelate on an example of a well understood product – customizable pen. Each activity is implemented via two components: an interactive computer game and a physical display environment, which complement each other. The results of an observational study and analysis of the data gathered through a data collection mechanism built into the game are also provided, suggesting a successful achievement of initial design goals.

Introduction

Despite steadily increasing dependency of modern societies on technology, society-wide understanding of technology (necessary, for example, in informed and critical decision-making) is usually lacking. Since about 70 percent of Americans are past the school age, updating their technological literacy requires access to opportunities outside of formal education. Younger generations have yet to develop their technological skills and interests, but opportunities for that in a structured, pre-college education are limited. The importance of inducing technological interests in youth cannot be overstated, as it impacts future supply of engineers and scientists.

Being avid consumers of manufactured products, contemporary American youths are very familiar with their wide variety 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 simultaneously 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 Overall, general public's knowledge of manufacturing is relatively limited; also its perception is really outdated (usually stuck in mass production concepts) and unappealing.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.

This paper describes an effort to bridge the technological literacy gap, by a museum exhibit, offering a visitor-centered informal learning experience, highlighting the principles of modern manufacturing.

Exhibit Goals and Development

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

are intertwined in development of manufactured goods. A secondary goal of the exhibit is to introduce children, especially girls, to the types of professions found in these areas so they may consider them as future career choices[3]. 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.

Typical exhibits in an hands-on museum require a great deal of development effort. On average it takes 2 to 3 years, a solid budget (anywhere from $100,000 to a few million in extreme cases, depending on complexity), and a diverse team working full time to create an individual interactive exhibit. Similar effort was invested in the exhibit described here, except that the team consisted mostly of students, who were contributing to the project only part-time. Involved students, both graduate and undergraduate, were coming from various disciplines, including mechanical and software engineering, economics, education, business and art design.

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 houses the computer equipment [11]. These parts are designed to complementarily satisfy the three goals of exhibit design, mentioned above. The physical display environment is developed to attract the visitors and support the knowledge acquisition by presenting content materials and graphic instructions for the games. 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 is facilitated. The exhibit is intended for participatory, informal learning institutions, and as such was designed to target the majority demographic of those institutions, children of the ages 6 – 12 [12]. Thus the terms “visitor” or “user” employed later on in this text should be interpreted as a reference to a member of this target population.

Figure 1: Layout of the Design Station exhibit in a museum setting.

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 usually crowded 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, related to 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.

Figure 2: Opening screen from the Design Game.

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.

Attracting Visitors

The role of informal learning environments, particularly museums with interactive science exhibitions, has been argued in contemporary theories of education [2, 9]. 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.

The 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 [10]. 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.

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. 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 exhibits 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. In this context, the exhibit – *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 [10]. Cognitive theories suggest that that human mind has the ability to most efficiently process information organized into 3-5 information chunks. 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

The purpose of motivating visitors to interact with the exhibit is relatively straightforward: prior research shows that the longer a visitor interacts with an exhibit, the greater the possibility that learning has been facilitated [18].

The power of narrative, first-person stories to engage visitor interest in a museum exhibit has long been acknowledged in museological research [16]. 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.

Figure 3: Screen shot introducing the market research task.

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 [17].

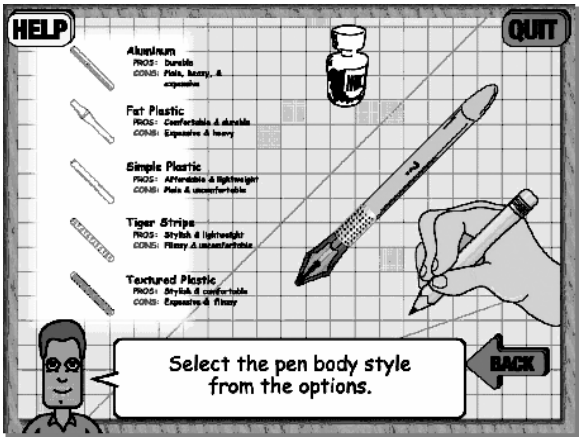

Figure 4: Screen shot from one of the pen design steps.

Another strategy to lengthen the visitor interaction time draws 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 [15]. 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 2 and 3).

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 [3, 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. 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 [1, 4]. 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.

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. 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. 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."

Facilitating Learning

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.

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 [13]. 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. 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 5) [7]. 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.

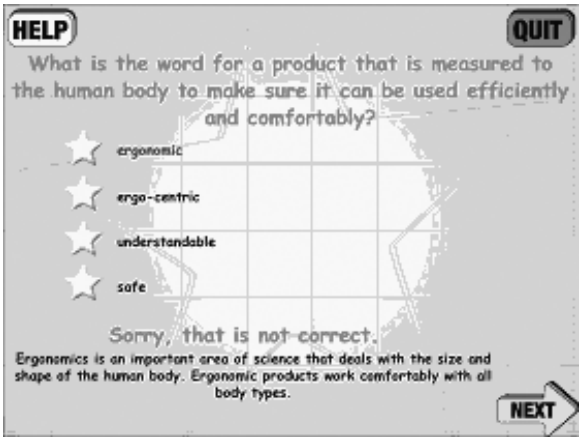

Figure 5: Screen shot of the in-game Bonus Quiz.

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 [6]. 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. 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 game topics, and to outline the chunks of the information with concise text and graphic illustrations.

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." [8]. 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." [6].

Assessment of Visitor Behavior

In an attempt to gauge 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.

The data indicate some gender differences amongst visitors: more females than men played the game, 57% to 43%, a trend that held across virtually all age groups [14]. Interestingly, females scored significantly better on the in-game pen design task as compared to males. This result indicates equal appeal of the game to both genders.

Collected information provides an interesting view of the users' experiences (and hence hints for the successful game design). A surprisingly large number of visitors, nearly half (48.2%), played the game to completion (defined as any stage from the score screen until the credits). This is quite an achievement for a game placed on the floor of a busy science museum. Even so, it is an examination of the "early quitters" that really provides some interesting insights into the game. For example, the largest spike of users abandoning the game prior to completion occurs at the final stage of three screens of text-based instructions, suggesting that the users who chose to quit at this point did so because the interactive task, as described to them by the instructional screens, did not seem appealing.

A correlation check across the game scores, time spent playing the game, and the number of clues discovered and utilized by the subjects shows that our game scoring reflects in-game behavior appropriately. This is an important finding, because it is quite possible to build a piece of "educational software" that has a veneer of educational content, but whose gameplay mechanics contain nothing that intrinsically leads to deeper learning.

Data logs of individual gameplays provide rich data set for analysis of various effects impacting the final user score. The complexity of the data, however, often impedes proper interpretation – even if the data shows correlations, it is often difficult to explain causal mechanisms, and in particular, fully understand the learning process. The results indicate though, that compared to random selection success rate of 42%, on the average visitors were scoring at 60% levels across all age and gender groups. Unfortunately data tracking does not allow to identify repeat plays by the same visitor, so it was not possible to track performance improvements due to learning. While responses to Bonus Quiz questions on the game exit yielded on average 80% of correct answers, but since they were optional, only about 15% of visitors have chosen to answer them.

Extending the Museum Experience

While the interactive experience with the exhibit on the museum floor is in itself rewarding to the visitors, to effectively amplify the learning process and leverage initial visitor(s) interest, a follow up extending beyond museum environment should be created. Some natural avenues for such extensions exist. The most obvious is the web-based version of the game, with some of the supporting material, which is already available on the internet, even though currently for testing purposes only (http://erc.engin.umich.edu/museum/). Another alternative is CD-ROM version of the game, which can be played on a stand-alone computer, and can possibly be also available as a take-away item in the museum. While these versions of the game have been created from the existing game code, they have not been equipped with user-tracking mechanisms due to practical and legal reasons. Yet another possibility for further distribution of the game exists through the Manufacturing Resource Center website (MERC online http://www.merconline.net/), where some of the related materials have already been deposited.

Summary and Future Work

All of the initial observations suggest that the exhibit has achieved its initially defined goals. The preliminary results show that among the goals of the project, motivating the visitors to engage with the game content was 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 was also 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.

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