Stimulating visitor experience in museum exhibits dealing with the micro world

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Key words: exhibit, experience, museum, evaluation, micro world, interactivity.

Abstract

In this report, the evaluation of the new interactive exhibit the Cell Zoomer is discussed. The Cell Zoomer, in Naturalis Biodiversity Center in Leiden, the Netherlands, is used as a case study for exhibits dealing with the micro world, to find characteristics of the exhibit that stimulate visitor experience.

The study shows that visitors capable of interacting with the Cell Zoomer were very positive about its design. Especially the interactivity and the physical component therein were considered to aid visitors in their experience. However, due to the minimal instructions, many visitors had trouble finding out how to use the exhibit.

It is concluded that interactivity (especially for the younger public) and clear instructions are very important characteristics of exhibits to stimulate visitors' experience on the micro world. Additional stimulating characteristics are the use of real pictures, the presence of physical components in the interactive features and an attractive look, which can be created by a large size and moving images.

Introduction

Public interest in advancing scientific fields dealing with the micro and nano world, like genomics and nanotechnology, is rapidly growing (Lee *et al.*, 2005; Schummer, 2005). However, as the public is generally unfamiliar with things they cannot see, there is a need to raise awareness and provide information on the micro and nano world (Bequette *et al.*, 2011; Lee *et al.*, 2005; Waldron *et al.*, 2006). This has resulted in many challenges in the communication with the public on new discoveries in these fields and the potential use of related technologies (Araújo-Jorge *et al.*, 2004; Dijkstra & Critchley, in press; Murriello *et al.*, 2006).

Science museums are important places for communicating ideas on these scientific fields with the public (Bell *et al.*, 2009; Falcão *et al.*, 2004; Falk & Dierking, 2010; Nisbet & Scheufele, 2009). Science museums have spent increasing amounts of time and resources in the last decade, creating new exhibits dealing with these topics. They often focus on making the micro world visible and making the relation with the macro world better understandable (e.g. Beaudoin, 2009; Ellenbogen, Dancu & Kessler, 2004; Klinger, 2009; Ma, 2007, 2008a, 2008b). To maximize the impact these exhibits have, evaluation is crucial (Kelly, 2004; King, 2010; Rattloff, 1998; Screven, 1990).

The aim of this study is to find those exhibit features that are most important in helping visitors understand and experience the micro world. Within this study, the micro world will be considered to be 'everything that is too small to be seen by the naked eye'.

Central in this study is the evaluation of a new exhibit. This exhibit is the Cell Zoomer, in Naturalis Biodiversity Center, Leiden, the Netherlands. It is an interactive exhibit showing new scientific material and has great potential in helping visitors understand and experience a part of the micro world.

Museum learning and experience

As Falk and Dierking (2010) say *'school is not where most Americans learn most of their science*'. One of the pivotal places they put forth as important educational resources for the public are science museums. Science Museums are seen as continuing, lifelong educational opportunities to the general public (Falcão *et al*., 2004). On first impressions, science museums are '*an appealing educational alternative to a school science classroom*' (Allen, 2004). As Allen (2004) discusses, this is because hands-on activities can be found in these museums that are filled with stimulating, multi-sensory fun, all based on scientific evidence. There is ample room for personal choice and no teachers demanding boring, obligatory tasks. There is no curriculum and there are no tests. However, according to Allen, these are also exactly the reasons why science museums are difficult places to invoke learning.

As a result, there have been many attempts in the last decades to investigate learning effects in museum visits (Allen, 2002; Anderson *et al.*, 2003; Ansbacher, 1998, 1999; Boisvert & Slez, 1995; Bollo & Pozzolo, 2005; Ellenbogen, Luke & Dierking, 2004; Falk & Storksdieck, 2005; Griffin *et al.*, 2005; Gutwill & Allen, 2010; Hennes, 2002; Kimche, 1978; McManus, 1987; Murriello *et al.*, 2006; Osborne & Wittrock, 1985; Rennie & Johnston, 2004; Rennie & McClafferty, 1995). One conclusion one can draw from all these studies is that not much is certain when it comes to learning in museums. As Osborne and Wittrock (1985) already succinctly said: *'Any model to do with human learning is an oversimplification of reality.'* However, this has not deferred researchers from designing models, as models are needed to measure the learning effect of museum exhibits on visitors. One of the more encompassing models is the Contextual Model of Learning, as discussed and used by Falk and Storksdieck (2005). This model consists of twelve 'suites of factors', divided over three groups (personal, sociocultural and physical), that were found to be influential in museum learning. They found that no single factor could adequately explain visitor learning. Similarly, Griffin *et al.* (2005) use the influence of different factors in the definition for museum learning they use: *'Museum learning is a dynamic process dependant on the individual and their environment within a social context that focuses on some change.'*

Other authors focus on specific aspects, like the social (i.e. Allen, 2004; Ellenbogen, Luke & Dierking, 2004; Gutwill & Allen, 2010) or the more personal aspects (i.e. Anderson *et al.*, 2003; Rennie & Johnston, 2004). According to Rennie and Johnston (2004), learning is personal, based on context and takes time, which makes it hard to study. Anderson *et al.* (2003) discuss some of the controversy on the meaning of (museum) learning, providing many different definitions and ideas on learning. They advocate the idea of 'human constructivism', as proposed by Mintzes *et al.* (1997), which recognizes individual's prior knowledge and personal involvement in knowledge construction, as well as *'the dynamic*

nature of knowledge construction' (Anderson *et al.*, 2003). Human constructivism has many similarities with the conclusions from Ansbacher's studies on John Dewey's educational philosophy (Ansbacher, 1998, 1999). In summary, the main principle of Dewey's philosophy is that *'all genuine education comes about through experience'* (Ansbacher, 1999).

Following Dewey's ideas on learning, experience is the basis for learning and is, as such, a term that can be seen as encompassing cognitive, affective and physical stimulations to visitors. Visitor experience is affected by visitors' previous experiences, their personal knowledge and ideas on the exhibit subjects, as well as on the environment (sensorial stimulation, morphology of the space of the exhibit and its surroundings) and the exhibit design (Bollo & Pozzolo, 2005; Griffin *et al.*, 2005).

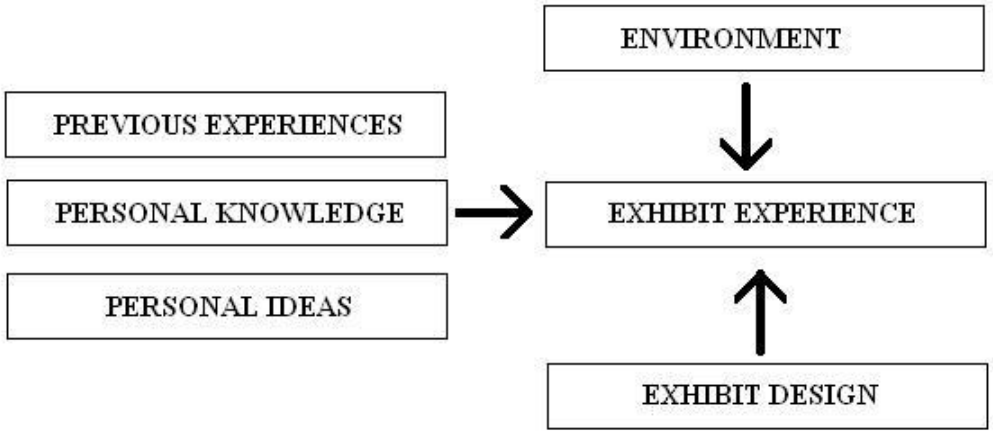

Figure 1: Overview of factors influencing visitors' exhibit experiences.

Goals of science museums

In the last decades, there has been an ongoing debate on what the goals of science museums should be (Ansbacher, 1999, 2000; Ansel, 1996; Bell *et al.*, 2009; Garnet, 2001; Hennes, 2002; Higgit, 2011; Nisbet & Scheufele, 2009; Ovenden, 2004; St. John & Huntwork, 2005). The importance of experience, opposed to pure learning (knowledge construction), plays a pivotal role in this debate.

Hennes (2002) proposes that museums should offer ways to expand visitors' priorities into *'richer purposes and interests'*, with an emphasis on experiental value. This is similar to the idea of St. John and Huntwork (2005) that experiental literacy is as important as a goal as providing information. They say that experiental literacy suggests that '*the understanding of science concepts has much greater meaning when conceptual understanding is grounded in rich personal experiences of phenomena'* (St. John & Huntwork, 2005). This idea is related to the Experiental Learning Theory, which argues that learning results from the integration of conceptualizing experience and the reflection on experimentation (Mainemelis *et al.*, 2002). Ansel (1996) also emphasizes on the role of experience, indicating that the main goal for science museums should be to encourage rich, engaging personal experiences. Ansbacher

(1999, 2000) makes similar claims, saying that *'museums are, above all, places which provide experiences'* (Ansbacher, 1999) and that *'the exhibit experience is no longer just a means to an end, it is an end in itself'* (Ansbacher, 2000). Ovenden (2004) sums this up by stating that museums should excite, thrill, fascinate and inspire their audiences with real objects.

Most of these ideas are built from those of Frank Oppenheimer, who in 1968 already stated that the purpose of a science museum is to '*satisfy the need people have for an environment in which they can become familiar with the details of science and technology by controlling and watching machinery.'* He was advocating the important role personal experience should have in museums and was one of the first to really use interactive exhibits to increase experience in a science museum.

Especially for exhibits dealing with the micro world, stimulating experience is important. Because the exhibits deal with things that are, normally, not visible and therefore unfamiliar to the public, these subjects are often found difficult (Bequette *et al.*, 2011; Flores *et al.*, 2003; Lazarowitz & Lieb, 2006) and the exhibit forms for many visitors a first introduction in this world. Experience, as the basis for all learning (Ansbacher, 1999) is therefore vital.

Following these ideas, this study focuses on exhibit experience, rather than on learning. The multitude of factors influencing experience makes it difficult to measure (see figure 1), but as the design of the exhibit is the part designers can influence, it is more useful to look at the performance of the exhibit than at that of visitors (Hennes, 2003). Naturally, to achieve the best results with an exhibit, all factors have to be studied and taken into account. A short study on visitors' ideas of cells was performed in Naturalis. This study showed that many visitors had a very simple idea of what cells look like and that many misconceptions concerning cell shape and cell size were present in different groups of visitors. However, following Hennes (2003), in this report of the evaluation of the Cell Zoomer, we will only discuss the effect of the design of the exhibit on visitor experience.

Interactivity

To promote both learning and experience in exhibits, interactivity has often been used, with satisfactory results (Allen, 2004; Bequette *et al.*, 2011; Bishop *et al.*, 2007; Kimche, 1978; Klinger, 2009; Ma, 2008a, 2008b; Murriello *et al.*, 2006; Oppenheimer, 1968; St. John & Huntwork, 2005). McLean (1993: p. 93) defines interactive exhibits as *'those in which visitors can conduct activities, gather evidence, select options, form conclusions, test skills, provide input, and actually alter a situation based on input'*. Allen and Gutwill (2004) conclude that interactivity helps with the learning process. This is partly due to the increased recall of actions visitors have from interactive exhibits (Maxwell & Evans, 2002). Allen and Gutwill (2004) link this effect to Piaget's constructivism, concluding that the interactivity helps people to assimilate new information with existing conceptual structures in their mind. As an added bonus, interactive parts in exhibits increase visitors' engagement with the exhibit, as well as the time spend at the exhibit (Boisvert & Slez, 1995; Kimche, 1978)

However, interactivity is not a necessity for learning (Allen, 2002; Allen & Gutwill, 2004), nor has it always a positive effect. As McLean (1993: p.16) puts it: *'rows of buttons and levers may exercise some visitors' fingers and arms, but not necessarily their minds'*. Gutwill and Allen (2010) also discuss that interactive exhibits often do not call for advanced inquiry strategies by visitors. In interactive designs, there are several common pitfalls (Allen & Gutwill, 2004), which can be responsible for the less than positive effects on learning. Most importantly, they conclude that it has to be clear which interactive feature is the most important, because many features of equal priority can overwhelm visitors. Also, simultaneous use by different visitors can disrupt the exhibit and visual representations that are too bright and outstanding have a chance of overwhelming visitors.

Cell Zoomer

The Cell Zoomer is an example of an interactive exhibit, as visitors can 'alter a situation based on input' (McLean, 1993). The image shown by the Cell Zoomer is completely dependent upon the actions of the visitor.
The exhibit enables visitors to zoom in and out of a zebra fish (*Danio rerio*) embryo, from the complete specimen to specific cells and organelles. The latter are clearly visible at the highest magnification, which is 500,000 times. Visitors have to zoom in (and out) using their hands, moving them apart (or toward each other) on the screen. First, they zoom in on light microscope pictures. When reaching 3200x magnification, these change into scanning electron microscope (SEM) pictures. Here, visitors can go to hotspots, where information is provided on certain aspects of the zebra fish's body.

The Cell Zoomer opened in March 2012 in Naturalis Biodiversity Center, Leiden, the Netherlands. It has been designed and created in cooperation with the Leiden University Medical Center and Cyttron II. It shows the first electron microscope picture of an entire (multicellular) animal (B. Koster, 2012, pers. comm.). The picture is built up from over 30,000 scanning electron microscope photos. The picture is made using a new technique, which allows for nanoscale resolution for tissues as large as $1mm^2$ (Faas *et al.*, 2012).

The Cell Zoomer is located on the fifth floor, in the room 'Research in the Netherlands'. This is the top floor of the museum. The floor generally consists of seven different semi-permanent exhibits, unified by the general theme of research in the Netherlands. As such, the subjects of the exhibits differ greatly, ranging from coastal processes to the dodo to cells.

With its unique characteristics of using relatively new technology (touch screen) to show unique scientific images in an interactive way, the Cell Zoomer is a very interesting case study of exhibits dealing with the micro world.

Methods

To be able to judge the success of an exhibit, the extent to which visitors engage with the exhibit has to be studied, in order to find out whether visitors do what they are hoped to do (Ansbacher, 2000). In addition, visitors' opinions and ideas on the exhibit are needed to be able to know the effect it has on visitors' experience (Griffin *et al.*, 2005). Following other evaluations and visitor studies, three main methods are used to answer these questions: observations, questionnaires and interviews (Allen, 2004; Bishop *et al.*, 2007; Ellenbogen, Dancu & Kessler, 2004; Heffernan, 1998; Kelly, 2004; Ma, 2008a, 2008b; Rennie & Johnston, 2004; Screven, 1990; Wolf, 1980).

The main question in this study is 'What exhibit characteristics of the Cell Zoomer are important to stimulate visitor experience on the micro world?' To answer this question, the use of the exhibit the Cell Zoomer by visitors is evaluated. For this evaluation, three sub questions were formulated. These are 'What attracts visitors to use the Cell Zoomer?', 'How do visitors use the Cell Zoomer?' and 'What do visitors think of the features of the Cell Zoomer?'. Table 1 shows which methods are used to answer each sub question.

	Observations	Questionnaires	Interviews
What attracts visitors to use the Cell Zoomer?	X	X	X
How do visitors use the Cell Zoomer?	X	X	X
What do visitors think of the features of the Cell Zoomer?		X	X

Table 1: Matrix showing which methods are used to answer each sub question

Observations

On nine different days, observations were made of visitors of the fifth floor of Naturalis. These observations were made for exactly one hour. On different days, different hours of the day were used to observe.

During the observation hour, all visitors entering the exhibit room were counted, as were the number of visitors who touched the Cell Zoomer (users). These visitors were grouped by age: <12 years old, 13-20 years old, 21-50 years old and >50 years old. These groups represent four different types of visitors: children, teenagers, adults and elderly. Visitors were placed in one of the groups based on their appearance and the researcher's judgment.

At the start of the hour, the number of visitors present on the floor was counted. Similarly, at the end of the hour, visitors that still remained on the floor were counted. When calculating the percentage of users, compared to the number of fifth floor visitors, the number of users was compared with the number of visitors entering the fifth floor during the hour of observation. Since those that remained after this hour might still use the Cell Zoomer and were, in all likelihood, counted as entering the floor, this would lead to an underestimation of use. However, since those that were already present are partly counted as users, while not being counted as entering, this effect is compensated. As the numbers of visitors already present and those remaining are almost identical over the total hours of observation (51 and 50 respectively), this calculation of the percentage of users gives a fair representation of the actual use.

Following Boisvert and Slez (1995) and Bollo and Pozollo (2005), three variables are studied during the observations of visitors. These variables, which are indirect measures of the educational impact of an exhibit, are attraction, holding power and engagement.
Attraction is measured by the percentage of visitors who use the exhibit. Holding power is measured by the amount of time spent by visitors using the exhibit. Engagement is the degree to which visitors pay attention to the exhibit.

Boisvert and Slez (1995) distinguish three levels of engagement by visitors: Level 1: Involved time, level 2: Positive interaction and level 3: Instructional time. For the observations of visitors using the Cell Zoomer, these levels are redefined and specified as follows:
Level 1: Visitors who touch the exhibit, but do not zoom.
Level 2: Visitors who touch the exhibit, zoom in, but do not reach the electron microscope photos.
Level 3: Visitors who touch the exhibit, zoom in, reach the electron microscope pictures, but do not use the (information presented at the) hotspots.
Level 4: Visitors who touch the exhibit, zoom in, reach the electron microscope pictures, go to the hotspots and listen to the information presented there.

For extra information on visitors' engagement and their experience, visitors' interactions have also been observed. Ellenbogen, Luke and Dierking (2004) indicate that family conversations in museums have three different levels: 1) identifying, 2) describing and 3) interpreting/applying. These levels have been used to characterize visitors' interaction.

Questionnaire

Over four weeks, on twelve different days, including weekends and holidays, for several hours per day, all users of the Cell Zoomer were asked to fill in a questionnaire. A large majority of those users completed a questionnaire.
To be asked to fill in the questionnaire, visitors had to at least use their hands to zoom in and out. Children that were alone when using the Cell Zoomer were not approached, to ensure there was adult supervision that could be asked for permission.
Visitors were sometimes asked directly after using the Cell Zoomer, sometimes several minutes (up to fifteen) later, when leaving the floor. In total, 90 questionnaires were completed.

Interviews

During three different days, seven interviews were held with visitors who had just used the Cell Zoomer. All these visitors reached the SEM pictures. The interviews were held directly after visitors stopped using the Cell Zoomer. Unfortunately, due to malfunctioning equipment, not all interviews were recorded and, as a result, not all have been transcribed verbatim. However, results from these interviews are taken into account, using written notes made during the interviews.

Hypothetical Experience Trajectory

To evaluate the features of the Cell Zoomer and to be able to compare the results of the evaluation with the goals and the design, a Hypothetical Experience Trajectory (HET) has been created and used. The HET is based on the Hypothetical Learning Trajectory (HLT), which is discussed and used by Simon and Tzur (2004). The HLT is often used in the design process of educational material. It consists of the goal for the students' learning, the tasks that will be used to promote students' learning and hypotheses about the process of the students' learning (Simon & Tzur, 2004). For designing museum exhibits, we have adapted the HLT to fit the goals and design process of a museum exhibit. Like the HLT, the HET consists of three parts:

1) The goal for visitors' experience.
2) The design of the exhibit, indicating what visitors can see, hear, smell, touch or do.
3) Hypotheses about the process of visitors' experience, indicating a) how visitors should act with or by the exhibit and b) how these actions and the exhibit design would affect visitors' experience.

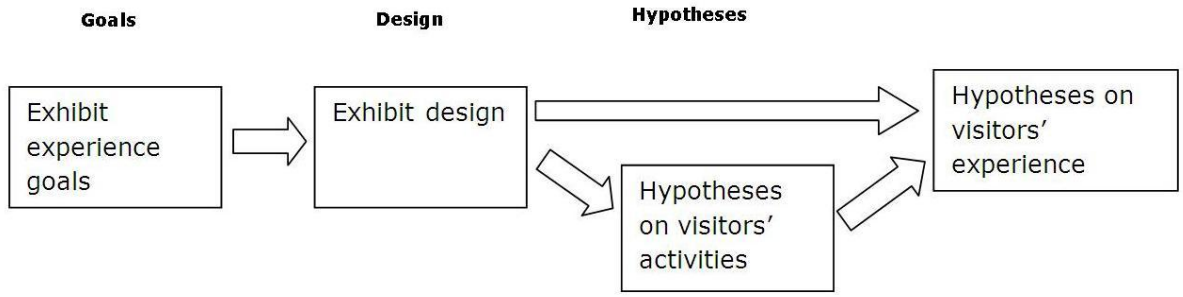

Figure 2: Model showing the basic components of the Hypothetical Experience Trajectory, and its relations.

HET Cell Zoomer

A Hypothetical Experience Trajectory of the Cell Zoomer has been made, using the information on the design process provided by the designers. The HET of the Cell Zoomer is portrayed as a diagram in figure 3. All aspects of the HET are discussed below.

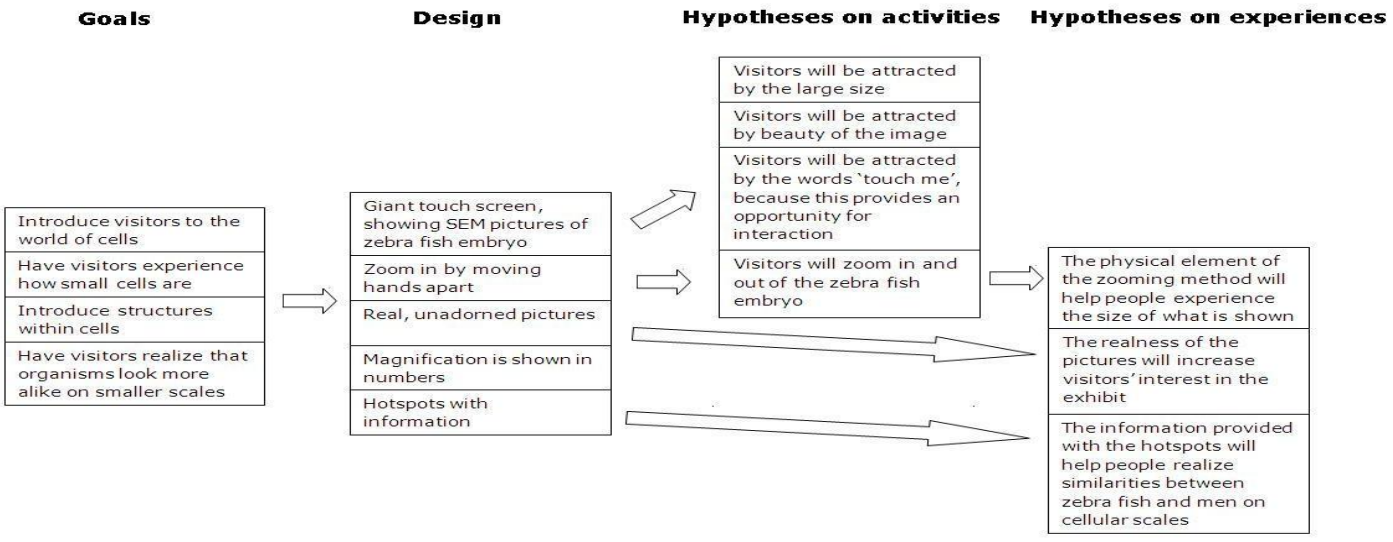

Figure 3: HET of the Cell Zoomer.

1) The main goal of the Cell Zoomer is to introduce visitors to the world of tissues and cells. Other goals are to have visitors experience how small cells really are and to introduce some of the structures that can be found in cells. Lastly, the exhibit aims to have visitors realize that organism look more alike on smaller (cellular) scales (I. van Zeeland, 2012, pers. comm.).

2) The exhibit consists of a large touch screen, 1.4x2m, and an information label that is directly attached to the left side of the touch screen (see figure 4a). The first image on screen is one of many zebra fish moving around on a black background, while the text 'touch me' is visible (see figure 4a). When the screen is touched by a visitor, the image changes to one showing light microscope pictures of one zebra fish and one zebra fish embryo. The scale of these pictures is 1:1 and they are set on a black background (figure 4b). A drawing of two hands is situated above, with two arrows pointing in different directions near the outstretched fingers. These are to indicate what visitors need to do next; zooming in (and out) on the zebra fish embryo, by moving their fingers away from (or toward) each other on the screen.
On screen, a number is shown to indicate the magnification. The zebra fish mother will also enlarge while zooming in. It will slowly move out of sight, as the screen is centered on the embryo (see figure 4c). At a magnification of 3200x, the light microscope picture changes into the electron microscope pictures. A small overview of the embryo is visible on top of the SEM pictures (Figure 4d). Visitors can continue to zoom using their hands, or they can touch the dots on the small overview of the zebra fish. Touching the dots will cause the image to zoom into that specific area (hotspots), where there is the option to listen to an audio fragment providing information about that area. Visitors can listen to these audio fragments by pressing the play button found on the screen.
On the information label attached to the touch screen, a little information is provided on cells, the creation of the electron microscope pictures and on the choice for the use of zebra fish in this exhibit. In addition, a small dish with real zebra fish embryos is shown (figure 4e).

3) The large size of the touch screen, as well as the image of the many moving zebra fish is supposed to draw visitors to the Cell Zoomer, using size, beauty and movement as attracting features. The text 'touch me' is added to attract visitors to start using the Cell Zoomer and to provide information on how to do this. The method of zooming has been designed to incorporate a physical element in the action, to give users a better feeling for the size of the depicted parts of the zebra fish. Visitors really need to 'dig' into the embryo to reach smaller parts of its body. The audio fragments often draw attention to similarities between zebra fish and humans, to help visitors draw those connections. All pictures shown are of a real specimen and have not been colored or changed in any way. This is done based on the belief that the realness of the pictures increases visitors' interest in the exhibit.

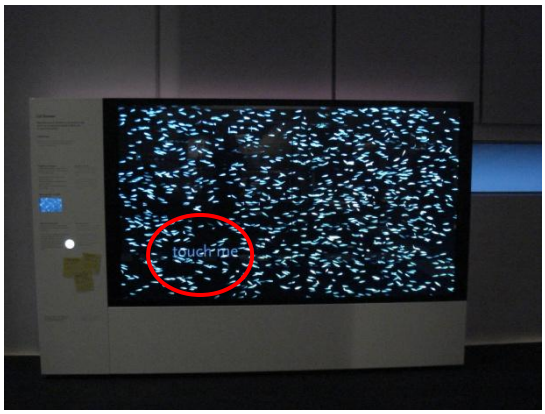

Figure 4a

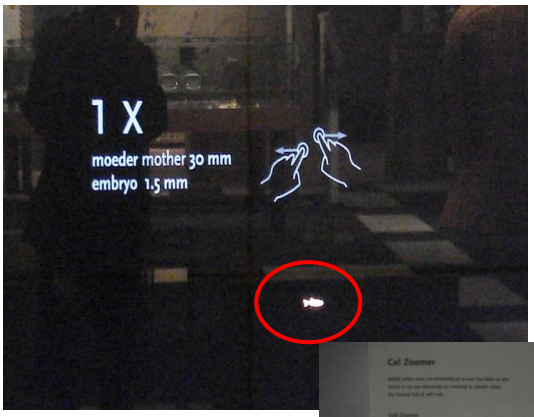

Figure 4b

Figure 4c

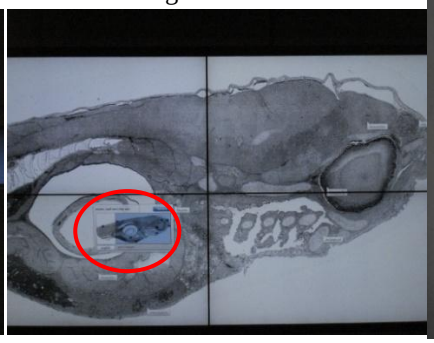

Figure 4d

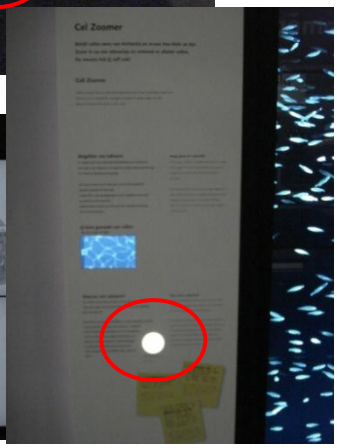

Figure 4e

Figure 4: All red circles have been added in the pictures by the authors to indicate certain features.
a) The Cell Zoomer with its opening screen of many moving zebra fish and the text ‘touch me, shown within the red circle. b) Center of the screen of the Cell Zoomer after the first touch, portraying the zebra fish mother and embryo on a scale 1:1 (within the red circle). Above these are shown two hands with pointed fingers, and two arrows pointing away from each other. c) The screen of the Cell Zoomer after reaching a magnification of 165x (magnification shown within the red circle). The mother zebra fish is partly off the screen, as it is centered on the embryo. d) The screen of the Cell Zoomer after reaching a magnification of 3200x, the first moment the SEM pictures are shown. Note the small overview of the total picture (within the red circle). e) Information label attached to the Cell Zoomer. Note the small, light circle near the bottom, which shows real zebra fish embryos (within the red circle).

Results

Observations

During the nine hours of observation, 404 visitors of Naturalis entered the fifth floor. In total, 51 visitors were already present on the floor at the start of the observations and 50 visitors still remained after the hour of observation (see Methods).

Attraction

In total, 121 visitors used the Cell Zoomer, 30% of the total visitors of the fifth floor. Six of these used it twice during the observation period. The users were mostly children (age <12) or adults (age 21-50), see figure 5. These are also the age groups that visited the fifth floor the most. Teenagers and children that visited the fifth floor had the highest percentage of users

(37.7 and 32.4% respectively, see figure 5). Men and women used the Cell Zoomer equally, with 64 women and 63 men using the exhibit.

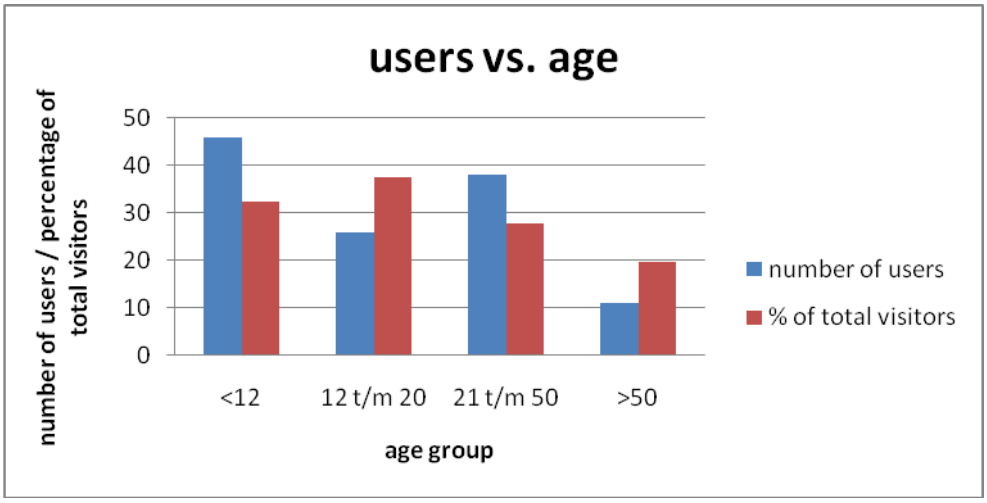

Figure 5: Graph showing the total number of users of the Cell Zoomer per age group, as well as the percentage of users compared to the total visitors of the fifth floor, per age group.

Holding power

On average, users spent 110 seconds with the Cell Zoomer. Just over sixty percent of the users spent less than ninety seconds at the Cell Zoomer (61.4%, 78 users). Half of the other users (20.5%, 26 users) spent more than three minutes with the Cell Zoomer (see figure 6). Men spent, on average, more time with the Cell Zoomer than women, 126 seconds versus 94 seconds.

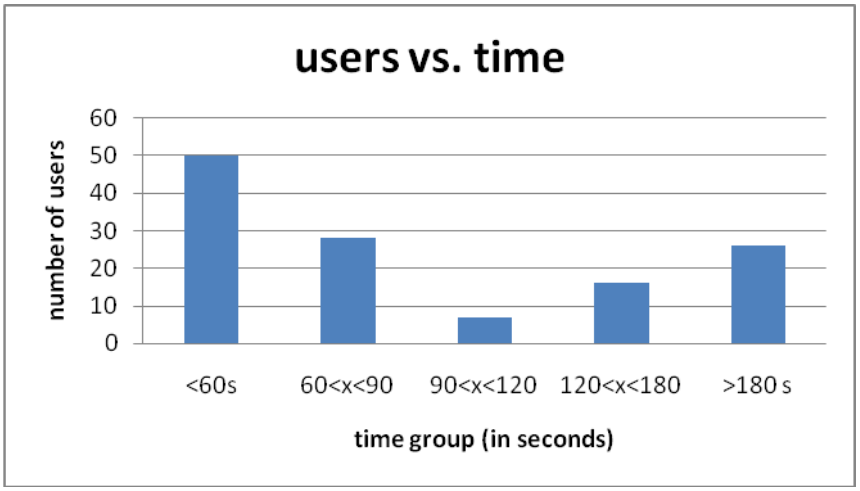

Figure 6: Graph showing the number of visitors that used the Cell Zoomer for <60s, 60-90s, 90-120s, 120-180s and >180s.

Engagement

Forty percent of the users (50 users) had an engagement level of 1 (touching the exhibit, but not zooming). Most of these visitors did not zoom in because they could not figure out how to do this (noted during observations). In total, 31.5 percent of the users (40 users) were unable to interact with the exhibit the way visitors were meant to. This was specifically a problem for

elderly (age >50). More than half of them (54.5%) were unable to zoom in. Teenagers were particularly good in figuring out the zooming process, with only 7.4% (2 users) that were unable to zoom in (see figure 7).

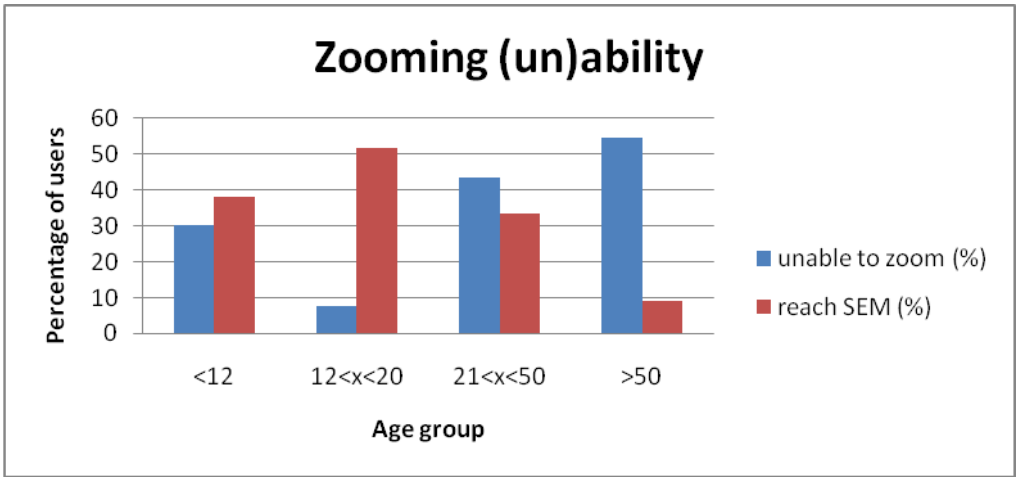

Figure 7: Graph showing the percentage of the users of the Cell Zoomer that were unable to zoom (did not understand how to do it) in blue, and that reached the SEM pictures, in red, per age group.

Of the users who did figure out how to zoom in and out, forty-seven (37% of the total number of users) reached the SEM pictures (engagement level 3 and 4). Slightly more than half of these (25) used the hotspots and listened to the audio fragments. These users were mostly below 20 years old, with nine children and nine teenagers using the hotspots (see figure 8).

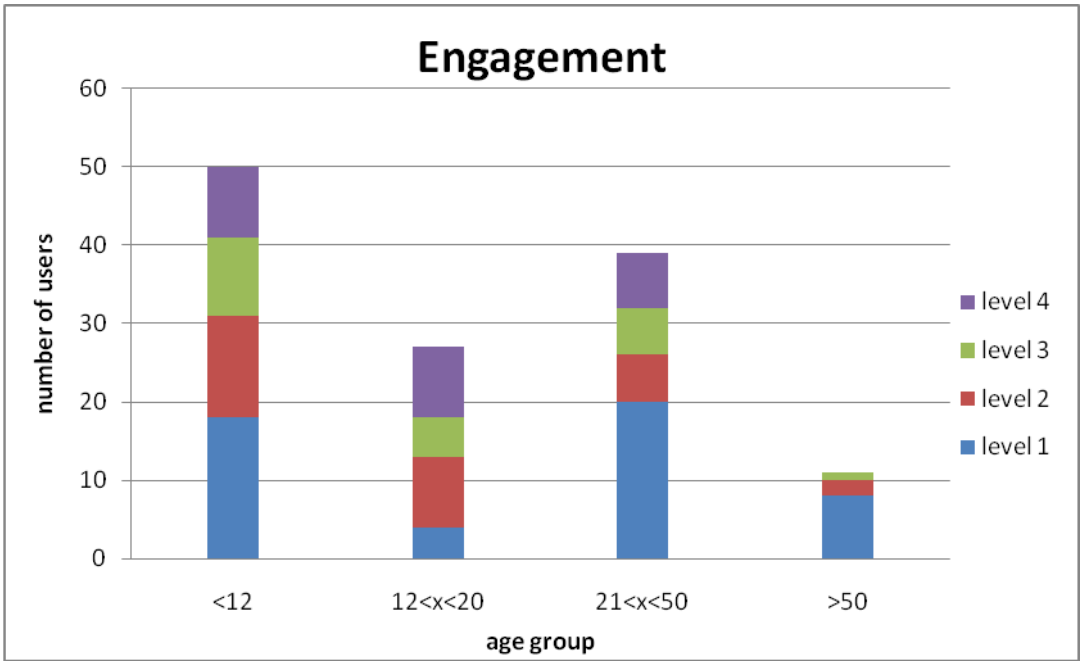

Figure 8: Graph showing per age group the number of users for each engagement level (see Methods).

Interaction

Only half of the users (65) interacted with other users. Of these interactions, most were of an identifying level (30). These visitors made statements like ‘wow, so big!’ or ‘look, fish’. Only

seven visitors interacted in a way that could be seen as interpreting/applying, discussing similarities between fish and men. These visitors all had an engagement level 4.

Questionnaire

In the questionnaire, visitors were asked to pick what aspect of the Cell Zoomer attracted them to use the exhibit. They could choose from the options 'the size of the screen', 'the beautiful picture', 'I like fish', 'other visitors using the exhibit', 'the moving picture' and 'an interest in cell biology'. In addition, they had the opportunity to add other reasons why they were attracted to use the Cell Zoomer. It was explicitly stated that they could give several answers.

In addition to the question on attraction, visitors were asked to fill in a likert-scale on how much they agreed with seven (independent) statements related to specific features of the Cell Zoomer (other than attraction). In the likert-scale, 1 stood for 'completely disagree', 2 for 'disagree', 3 'neutral', 4 'agree' and 5 'completely agree'.
The seven statements visitors were asked to rate this way were:
1) Real images are more interesting than drawn images.
2) I realized I was looking at a real photo.
3) It's a shame the images are black and white.
4) It is clear how large the components on the screen are in reality.
5) Using my hands while zooming strengthens my idea of scale of the image.
6) I would like for someone to explain things of the exhibit.
7) Now that I've used the Cell Zoomer, I would like to know more of cells.

In total, 90 visitors completed the questionnaire. Of these, one did not fill in the general section (on age and sex) and two did not answer on one of the statements (once number 3 and once number 7).
The 89 visitors who gave their age group and sex, 42 were male, 47 female. The distribution of the age groups is shown in table 2.

age group	n
<12	15
13-20	15
21-50	48
>50	11

Table 2: Number of visitors that completed the questionnaire per age group.

Attraction

All standard options provided in the questionnaire on attraction were given as a reason by at least one visitor. In addition, twelve other reasons were given. One of these, the text 'touch me', was given by several individuals. The others were only given once and were generally related to the interactivity of the exhibit.
In table 3, all answers that were given more than once are shown, with the total number of answers. For each age group, these numbers are shown separately as well.

The size of the screen and the picture on it are the most answered attracting features of the exhibit. Especially for teenagers and adults, the size of the screen is important. Fifty percent of these groups names this as (one of) the reason(s) for being attracted to the Cell Zoomer. The beauty of the picture and the fact that it shows moving objects (zebra fish) are both named by approximately one third of the visitors. In total, 53 visitors name either the beauty or the moving aspect of the picture as attraction. Eight of these name both.

Frequency / Attraction	Total (n=90)	<12 (n=15)	13-20 (n=15)	21-50 (n=48)	>50 (n=11)
The size of the screen	38	2	8	24	4
The beautiful picture	32	5	5	17	4
I like fish	8	3	1	3	1
Other visitors using the exhibit	9	2	2	4	1
The moving picture	29	4	6	17	2
An interest in Cell Biology	9	3	1	3	2
Text 'touch me'	13	1	2	9	1

Table 3: Total number of people that provided each answer on the attraction question, as well as the number of people for each separate age group.

Features

The average answers on all statements are shown in figure 9 (n= 90, except for 3 and 7, where n=89).

Almost 75% of the visitors (67 of 90) state that they agree with the statement that real pictures are more interesting than drawn images. Less than 10% (8 of 90) disagrees. Only thirteen people answered they did not realize they were looking at a real photo (statement 2).

The use of unadorned scanning electron microscope photos resulted in black and white pictures. Because the zebra fish embryo is transparent, even the light microscope pictures are largely black and white. On average, visitors are fairly neutral on this aspect. More visitors disagree than agree (41 and 26 respectively) with the statement that this lack of color is a shame.

Most users say that the Cell Zoomer shows clearly how large the components on the screen are in reality. Especially children (<12) agree with this statement: none disagree, only 3 (20%) answered neutral. For other age groups, the results are not as outspoken, but they show on average the same trend.

One of the most important features of the Cell Zoomer is the zooming method (see Cell Zoomer). This method, similar to that of an iPad, was chosen because the designers thought (hoped) that the addition of a physical aspect to the zooming would increase visitors' feeling for the scale. The results of this questionnaire show that visitors themselves agree that the use of their hands during the zooming strengthens their idea of scale. Sixty-two (69%) of the users

agree with this statement. For adults (age 21-50) this is even higher (79%). Other age groups have slightly higher percentages of people answering neutral. Disagreement with the statement is generally low, with children being the only group where more than twenty percent disagrees (33%).

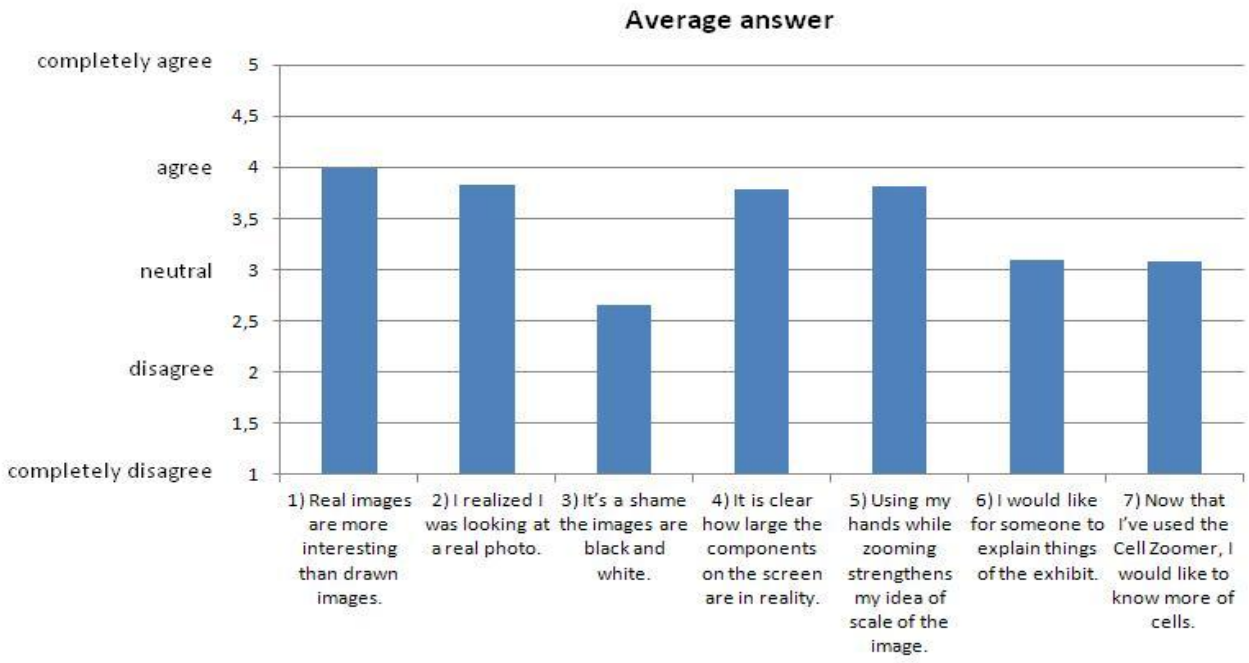

Figure 9: Graph showing the average answer on all statements

On the last two statements, on wanting someone to explain things of the exhibit (number 6) and on wanting to know more of cells after using the Cell Zoomer (number 7), the average answer was neutral (respectively 3.09 and 3.08). However, the distribution of the answers on these two statements is completely different. On number 6, only twenty one visitors answered neutral. The others were fairly evenly divided over disagree (32) and agree (37). On number 7 however, more than half of the respondents (47) answered with neutral. On both statements, elderly (>50 years old) answered more in agreement with the statement than the other age groups. Of the elderly, 64% answered in agreement with statement 6 and 54% with statement 7, for the other age groups, this was never above forty percent.

Differences between age groups

Some differences between age groups have already been mentioned. For all statements, Kruskal-Wallis tests were performed to see whether the means of the different age groups were from identical populations. H-values were calculated for all statements and compared to χ^2_α, with α=0.05 and three degrees of freedom (k-1, with k being the number of groups that are compared). This χ^2_α = 7,815 (Freund, 2004).

Based on these tests, no statement shows significant differences between the age groups except statement 6 ('I would like for someone to explain things of the exhibit.'). On the results of this statement, Mann-Whitney U-tests were performed between the two youngest

age groups versus the two oldest age groups, as well as within the youngest and oldest groups. No significant differences were shown, except between the groups 21-50 and >50. The group >50 has a much higher average answer than the other groups. To proof the idea that this group caused the rejection of the null hypothesis in the Kruskal-Wallis test, another Kruskal-Wallis test was performed, using only the other three age groups. Here, an H-value of 1.36 was calculated, leading to the acceptation of the null hypothesis that these three groups were not significantly different. Therefore, the >50 group answered significantly different on the statement on wanting someone to explain things of the exhibit.

Differences between sexes

For all statements, answers of men and women were also compared, using Mann-Whitney U-tests. This way, *z*-values were calculated and compared with $z_{2\alpha}$, which is 1.96 (α=0.05) (http://www.nyx.net/~tmacfarl/STAT_TUT/mann_whi.ssi). Only the results on statement 2 ('I realized I was looking at a real photo.') showed a significant difference between the sexes. Men answered more in agreement with this statement than women did.

Interviews

All visitors were first asked what they saw or noticed when using the Cell Zoomer. Since all visitors see something different in any exhibit, as a result from previous personal experiences (Griffin *et al.*, 2005), it was worth finding out what some individuals noted after using the Cell Zoomer. Considering that the main goal of the Cell Zoomer was to introduce visitors with the cellular world, one would hope visitors would give cell-related answers. However, most visitors answered they saw fish. Only one person answered that he saw different types of cells.

As in the questionnaire, visitors were asked what they thought of the lack of color in the images. The interviews provided similar answers as the questionnaires, with most people not minding the lack of color. As one woman said '*It's easier to see structures this way. With colors, you're going to be looking like, oh, nice, colors*'. However, opinions were divided, again similar to the questionnaires. One visitor said he would have liked to have some colors, showing the structures the information at the hotspots was about, because he had some trouble finding them.

All interviewees said that the Cell Zoomer gave a good indication of how small cells really are. The real size of what was shown on the screen was less clear, because not everyone could interpret the large number of magnification, which is shown on the screen, into an actual size. However, starting with the actual size of the embryo, as well as the dish with real embryos next to the screen, did help people's imagination in realizing how small cells are. The physical component of the zooming process was occasionally found to be helping with this as well. This result is again similar to that of the questionnaires. However, most visitors said they liked the zooming method, because they could do it themselves and it was '*modern*'. The

additional value of aiding visitor's idea of scale was far less common than visitors simply liking the interactivity.

In contrast to the questionnaire results, where most people were fairly neutral about the idea of an explainer next to the Cell Zoomer, all interviewees answered they did not want someone there. They liked being able to find things out themselves and thought that the information provided was enough. In fact, only one person wanted more information than provided, saying that, in general, she liked it when a lot of information was available. She would have liked more details on specific cells, and, when mentioned by the interviewer, said she would like more information on zebra fish and microscopy as well. However, she was the only one who really wanted more information. The large majority was very happy with the amount and type of information presented.

When asked whether the Cell Zoomer had reached its main goal, introducing visitors in the cellular world, all interviewees answered yes. However, as one man clearly proved, it is critical to reach the SEM photos and look at that. At first, he had not reached it and at that moment, he answered with a clear no on this question. However, when the SEM photos were shown on the screen, he was far more positive on this. All other interviewees had reached the SEM photos and had used some hotspots to navigate this part of the exhibit.

Discussion

The Hypothetical Experience Trajectory of the Cell Zoomer shows the designers added four main features that were expected to have specific effects on visitors' experience (see figure 3). The size of the screen and the image shown, including the text 'touch me', were thought to attract visitors to use the Cell Zoomer, the method of zooming was thought to help visitors with their idea of scale, the use of real images was thought to add interest to the exhibit and the information provided with the hotspots was hoped to help people realize similarities between zebra fish and humans on a cellular scale. The results show that these assumptions were, in general, right.

Attraction

The size and the image (both the beauty and the moving aspect) are the most common reasons visitors were attracted to use the Cell Zoomer.

The text 'touch me' was not one of the provided options on the questionnaire, but was still given as one of the reasons of attraction by almost 15% of the visitors. This indicates that it is an important feature to attract visitors. The text is transparent, changing from Dutch to English and popping up on different places on the screen. As such, it's not always as attracting as it could be, for it's not always easy to read, nor is it always in an opportune position to attract attention. As one visitor noted, it would probably be even more effective if the text would be shown in a bright color like orange. Nonetheless, the text showing the

touch-aspect of the exhibit, promising interactive features for the user, is potentially a powerful attracting feature. This could be given a more prominent role than has been done in the Cell Zoomer.

As thirty percent of visitors of the fifth floor started to use the Cell Zoomer, its power to attract visitors to use it was apparently not exceptionally large. One reason for this might be museum fatigue. This phenomenon, in which visitors view exhibits more cursorily after a period of time within this museum, is well documented (see Allen, 2002). As the Cell Zoomer is located on the highest floor of the museum, it is likely one of the last rooms visitors arrive in. Therefore, museum fatigue might well be a factor causing visitors that are attracted to the Cell Zoomer, not to use it. Another factor that can explain the rather low percentage of use is the location of the Cell Zoomer within the fifth floor exhibit space. It is located in the corner farthest away from the entrance and, as such, partially obscured by other, unrelated, exhibits. To increase its use, moving it to the front of the room or clearing more space around it will probably help.

Method of zooming

The method of zooming is considered by most visitors to help them with their idea of scale. Almost seventy percent answered that they agreed with the statement 'using my hands while zooming strengthens my idea of scale of the image'. Even though this is not by any means a definitive result showing that the physical component increases peoples feeling for scale, it is an indication that at least people think it helps. The importance of the physical aspects in museum learning is widely accepted and used (i.e. Bollo & Pozzolo, 2005; Falk & Storksdieck, 2005; Griffin *et al.*, 2005; Kimche, 1978; Murriello *et al.*, 2006; Oppenheimer, 1968). Combining this with the results of Minogue *et al.* (2006), who conclude that the addition of 'feeling' in their Virtual Reality of a cell enhanced students' perceptions of cells and improved people's ideas on spatial representations and relations between cell structures, it seems clear that the addition of a physical component does help people with their understanding. This is also in line with the learning theories of Piaget and Dewey (see Allen & Gutwill, 2004; Ansbacher, 1998). Additionally, the zooming method is often described as 'modern' and thought to be fun by visitors, enhancing their experience.

Real pictures

A large majority of the visitors answered that they thought real pictures were more interesting than drawn images. Considering that less than fifteen percent of the visitors answered that they did not realize they were looking at a real picture, it can be concluded that the pictures being real adds interest to the exhibit. This indicates that Naturalis' choice to use real pictures, rather than animations, even though these might be easier to understand, is justified.

Information with the hotspots

Of the 25 observed users of the Cell Zoomer that used the hotspots (engagement level 4), seven had an interaction level 4, indicating they realized there were similarities between the

zebra fish and humans on the cellular level. Naturally, this does not mean that none of the other visitors had similar thoughts, only that they did not discuss these with other visitors. Since all visitors with interaction level 4 used the hotspots, it seems safe to conclude that they form a necessary part of the exhibit to complete this goal of the Cell Zoomer. For almost thirty percent of the hotspot users, it had, demonstrably, the desired effect. The weakest part of the hotspots is the low use of them, with only twenty per cent of the visitors that start to use the Cell Zoomer actually using the hotspots.

Instructions

Judging by the results discussed above, the Cell Zoomer is well designed and popular with visitors. Indeed, those visitors that used the Cell Zoomer to its full extent were very positive and often praised key features of the exhibit. The interactivity was an important feature in this praise. However, it is exactly this interactivity that is also responsible for diminishing the Cell Zoomer's success. Allen and Gutwill (2004) mention several pitfalls interactive designs can have. One of these is that the interactivity can be difficult to use for some visitors.

That is exactly the problem with the Cell Zoomer. Over thirty percent of the visitors that attempted to use the Cell Zoomer could not figure out how to use it. A large group of visitors was therefore thwarted in experiencing the exhibit the way it was designed. Especially elderly had problems finding out how to use it. As a result, they left the Cell Zoomer frustrated. To improve this, the instructions should be altered. With the Cell Zoomer, the designers chose to use minimal instructions, depicting only two hands and two arrows to indicate the method of zooming. Kirschner *et al.* (2006) concluded that guided instruction had superior effects on students' learning compared to more intuition driven instructions. The results of the evaluation of the Cell Zoomer support these results, showing that interactive exhibits need more guided instructions in order to ensure visitors can have the desired experience. Following Driscol (2000), different types of instruction would most likely produce the best results. In addition to the image of the hands, an animation and written instructions could be provided. This way, a larger percentage of users would be able to interact with the Cell Zoomer. Especially for the older users of the Cell Zoomer, this would be an improvement.

Goals

When looking at the goals of the Cell Zoomer, the results are not as positive as they are on the specific features. As over sixty percent of the users of the Cell Zoomer does not reach the electron microscope photos, and consequently do not see a single cell, the introduction to the world of cells fails for this large group of users. This is caused by users being unable to zoom in, as well as by users not zooming in far enough. As discussed, more guided instructions would decrease the number of visitors that are unable to zoom in. To have visitors zoom in far enough to reach the SEM pictures, they should be seduced to continue zooming. To achieve this, it should be more clear how far they can zoom in and what they can see and do when they zoom in further. Additionally, questions on screen invoking visitors' curiosity, like 'How far can you zoom?', would also increase the number of visitors reaching the SEM pictures.

Visitors that reach the SEM photos do indicate that they thought the Cell Zoomer formed a nice introduction into the world of cells. However, this is not what first comes to mind when asked what they saw. Here, the answer 'fish' was the dominant result. As such, most visitors do not realize the exhibit was aimed to introduce cells.

For the goal 'have visitors experience how small cells are', results are better. Once again, sixty percent does not arrive at the cellular level and can, as such, not appreciate cell size. Of those that do arrive at the SEM photos, results show that the Cell Zoomer does aid their experience of cell size.

Introducing structures within cells, as well as having visitors realize organisms look more alike on smaller scales, is dependent on visitors using the hotspots. As only twenty percent of the users does this, these goals are at best achieved for a very small part of the users.

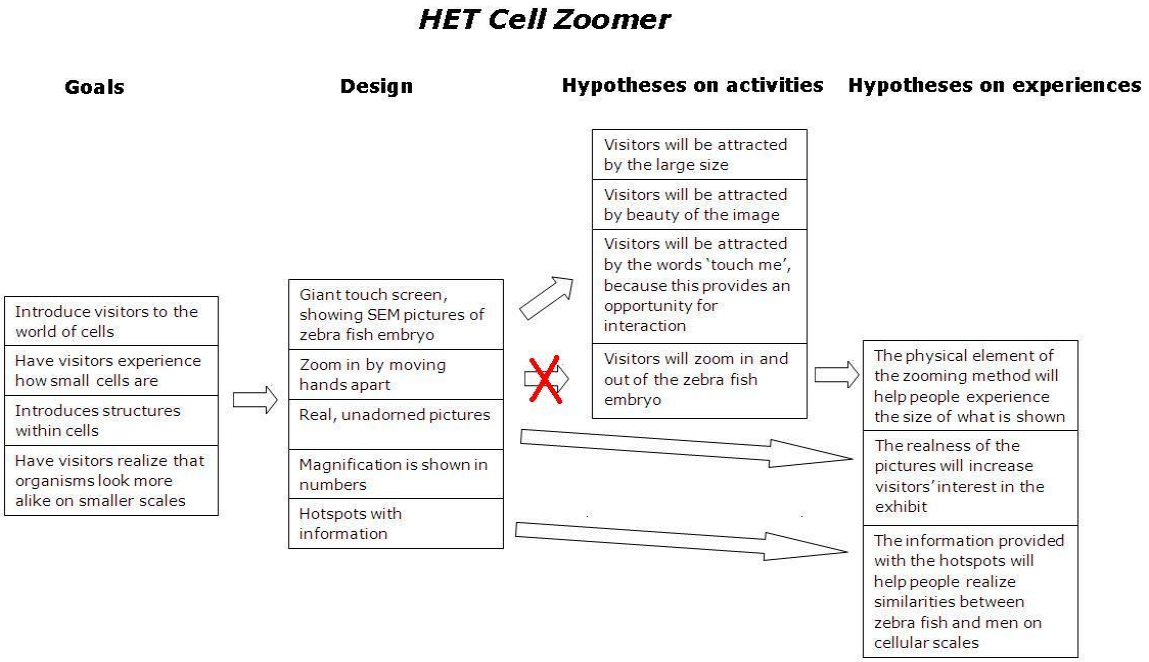

Figure 10: HET of the Cell Zoomer, showing which hypotheses are shown to be correct and incorrect. The red cross through the arrow indicates that a large group of users did not zoom in. All other designed features have their desired effect.

Conclusions

Experience is becoming more and more important in museum exhibits. Interactivity is an important characteristic of an exhibit to stimulate this. In interactive exhibits, clear instructions, preferably in multiple ways, are necessary to ensure visitors can experience the exhibit the way it was designed.

When designing and/or evaluating an exhibit, a Hypothetical Experience Trajectory (HET) is useful to create and use. In the HET, the goals and the design of the exhibit are described, as well as hypotheses on the effects of the design on visitors' actions and experiences.

The main features of the Cell Zoomer (the size of the screen and the image on it, the method of zooming and the realness of the pictures) have in general the desired effects on visitors who are using the Cell Zoomer as designed. The minimal instructions and specific method of zooming lead to a significant part of the users being unable to zoom in and 'correctly' use and experience the Cell Zoomer.

The physical component in the zooming method is thought to help visitors with their idea of scale. Visitors appreciate the use of real pictures and this does add interest to the exhibit. Beauty, movement and size attract visitors to the exhibit.

Especially younger visitors like to be able to decide for themselves what they see and do with an exhibit. Elderly prefer more straightforward information with less personal choice. Being allowed to touch an exhibit is considered to make it more interesting, especially by the youth.

To stimulate visitor experience on the micro world, interactivity (especially for the younger public) and clear instructions are very important characteristics. Additional stimulating characteristics are the use of real pictures, the presence of physical components in the interactive features and an attractive look, which can be created by a large size and movement.

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Appendix 1: Observation scheme Cell Zoomer

Age group	@ start	Visitors 5th floor	Users Cell Zoomer	Remain
4-12				
12-20				
20-50				
>50				

Visitor nr.	Age group	m/f	Time spent	Engagement level	Interaction with	Interaction level	Problem with zoom

Engagement level
Level 1: Visitors who touch the exhibit, but do not zoom.
Level 2: Visitors who touch the exhibit, zoom in, but do not reach the electron microscope photos.
Level 3: Visitors who touch the exhibit, zoom in, reach the electron microscope pictures, but do not use the (information presented at the) hotspots.
Level 4: Visitors who touch the exhibit, zoom in, reach the electron microscope pictures, go to the hotspots and listen to the information presented there.

Interaction level: 1) identifying, 2) describing and 3) interpreting/applying
Age groups: <12, 12-20, 20-50, >50
Problems with zoom: Yes, unsolved (Yu), Yes, but solved (Ys), No

Appendix 2: Questionnaire Cell Zoomer

Vragenlijst Cel Zoomer

Deze vragenlijst wordt gebruikt om te onderzoeken wat bezoekers van de Cel Zoomer vinden. Wilt u deze lijst invullen? Hierdoor kunnen wij in de toekomst nog betere tentoonstellingen maken. Alle informatie is anoniem.

Algemeen (*omcirkel uw antwoord)*
Ik ben een man / vrouw

Leeftijd: 4-12 / 13-20 / 21-50 / ouder dan 50

Cel Zoomer
Had u voor u naar Naturalis kwam al gehoord van de Cel Zoomer? (*omcirkel uw antwoord)*

Ja / Nee

Waardoor werd u aangetrokken om de Cel Zoomer te gebruiken? *(kruis het best passende antwoord aan; meerdere antwoorden zijn mogelijk)*

- De omvang van het scherm
- Het mooie beeld
- Ik hou van vissen
- Andere bezoekers die er mee werkten
- Het bewegende beeld
- Interesse in celbiologie
- Anders, nl. ……..

In hoeverre bent u het eens met de volgende stellingen? *(omcirkel het best passende nummer)*

	Helemaal mee oneens	Mee oneens	Neutraal	Mee eens	Helemaal mee eens
1. Echte beelden zijn interessanter dan getekende beelden.	1	2	3	4	5
2. Ik heb me gerealiseerd dat ik naar een echte foto keek.	1	2	3	4	5
3. Het is jammer dat de beelden zwart-wit zijn.	1	2	3	4	5
4. Het is duidelijk hoe groot de onderdelen op het beeld in het echt zijn.	1	2	3	4	5
5. Zelf zoomen met mijn handen versterkt mijn idee van schaal van het beeld.	1	2	3	4	5
6. Ik wil graag dat er iemand uitleg bij het scherm geeft.	1	2	3	4	5

7. Ik wil nu ik de Cel Zoomer heb gebruikt graag meer weten over cellen.	1	2	3	4	5

Hartelijk dank voor uw medewerking.

Appendix 3: Interview scheme Cell Zoomer

Ik werk voor het museum en wil graag weten hoe mensen denken over de Cel Zoomer, zodat we in de toekomst nog betere tentoonstellingen kunnen maken. Zou ik u kort een paar vragen mogen stellen? Het duurt ongeveer 10 minuten.

1) Wat heeft u gezien?

2) De beelden zijn bijna allemaal zwart-wit. Wat vindt u daar van? *(is dat jammer? had u graag meer kleur gezien? is het juist mooi?)*

3) Geeft de Cel Zoomer een goed beeld van hoe klein cellen zijn?

4) Om in te zoomen, moet u uw handen uit elkaar bewegen. Wat vindt u van deze manier? (*Heeft dit geholpen of zou u het liever anders willen doen?)*

5) Is het duidelijk hoe groot de vormen op het beeld echt zijn? Waardoor komt dat? *(de vergroting in getallen, begin met ware grootte, visjes ernaast)*
Wat zou u er anders/bij willen? *(bv. een schaalbalk, of een vergelijking met iets bekends)*

6) Zou u het fijn vinden als er iemand naast de Cel Zoomer zou staan, die uitleg over bepaalde onderdelen zou geven? *(vraag eventueel door naar waarom bij nee)*

Ja / Nee *(omcirkel 1)*

6a) *(bij ja)* Over welke onderdelen zou u dan uitleg willen hebben? *(als er geen antwoord komt, geef mogelijkheden: zebravisjes, het maken van de foto's, cellen, specifieke onderdelen zoals spiercellen/hersencellen/hart)*

7) Bent u tevreden met de hoeveelheid informatie die gegeven wordt bij de tentoonstelling? *(Wilt u meer/minder? hoeveel info moet er bij een exhibit over cellen/microwereld? Waarover?)*

8) Zou u nu meer informatie willen hebben over cellen? *(of iets anders, bv. zebravisjes of elektronen microscopen)*

9) Het doel van de tentoonstelling was om bezoekers kennis te laten maken met de wereld van de cel. Vindt u dat we daarin geslaagd zijn? *(waardoor is dat gelukt? Waardoor niet? Wat zou het beter maken?)*

Hartelijk dank voor uw medewerking.

Administratie:
Geslacht: man / vrouw

Leeftijd: 4-12 / 13-20 / 21-50 / ouder dan 50