Interactivity and a "Virtual Biochemistry Laboratory"

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Introduction
Media have gradually become an ubiquitous part of the environment in most developing countries. Young persons are today immersed in media to an extent that might seem frightening to some elders. A fairly recent Stanford University study of a cross-section national random sample of American adolescents aged 8 to 18 years has indicated that their daily exposure of media messages approaches 8 hours per day! Although TV is the dominant medium, the use of computers and video games follow close behind. [D.F. Roberts, "Media and Youth: Access, Exposure and Privatization", *Journal of Adolescent Health*, 2000; 27S: 8-14] This implies that by the time American youngsters are finishing high school, they have spent more hours in front of a TV or computer screen - close to 20,000 hours - than they have spent in a classroom, or about 14,000 hours! Should not future educational efforts take this into account?

It must be the envy of any ambitious teacher to watch the intense concentration and attention displayed by a young person playing an interesting and captivating computer game. What if we could tap into the psychological or physiological mechanisms behind this behavior and make use of these in more “serious” learning situations? Putting texts and figures on a computer screen – essentially digitizing old textbooks - is obviously not enough. Interactivity is the hallmark of the computer games and would be a powerful component of whatever “e-learning” system we use.

Interactivity and Learning
As part of the celebrations in the year 2001 of the first 100 years of Nobel Prizes, an educational “Internet” production called “The Virtual Biochemistry Laboratory” (VBL) has been developed and launched. From the outset, the production was planned to be interactive. I will describe this production in more detail below – but I would first like to take a brief and very personal look into the history of interactive computer programming.
It struck me that before writing a chapter dealing with interactivity – or at least what I naively regarded as interactivity - I should perhaps look into what the computer and Internet linked community regarded as "interactivity". I therefore performed a "Google" search, using first the phrase "interactivity," and then "definition of interactivity". You may be surprised to learn that the first search yielded 360,000 hits and the second 45,000.

This result probably reflects the circumstance that "interactions" in a broad sense really is an ubiquitous activity. Any discussion between persons could be regarded as an interaction. In the literature, interactions, in the sense of such a "give-and–take" situation, have a long history. Plato’s dialogues and Galileo’s dialogues on the Ptolemaic and Copernican view of the solar system can be said to be examples of this approach.

Interaction in the sense of being able to influence a process or phenomenon has probably a much shorter history. I will stick to the view of interactivity as a kind of general message loop – entities 1 and 2 connected in a "message" or "control" loop. This kind of interactive approach is obviously not new in the history of learning and has been implemented with great success many decades ago by leading science museums in the world – for example the Science Museum in London and the Exploratorium in San Francisco, to mention just two.
In the domain of computers, interactive programming also has a long history. I would like to go back to the days after the Second World War when modern computers and computing were in its infancy. That did not prevent a few brilliant pioneers to address some very basic and philosophical questions. In 1951 Alan Turing – sometimes called “the father of artificial intelligence” - wrote a paper in which he described a test of “true artificial intelligence”. He had in mind an interactive situation in which an interrogator was asked to try to distinguish a programmed computer from a real life person hidden from the interrogator, through the way they responded to his questions. Turing himself guessed that it would take some 50 years before an average interrogator would have a 70% chance of making the correct identification within 5 minutes.

But did Turing make a correct guess? Many computer scientists would probably tend to agree with him – but there is, in fact, a most remarkable exception: the interactive computer program called ”Eliza”, named after the cockney salesgirl who was picked up and “educated” by Professor Higgins in the play ”Pygmalion” (or ”May Fair Lady” as musical) by George Bernhard Shaw. This program was designed in 1966 by Joseph Weizenbaum at the MIT to mimic a psychotherapist. The visitor or ”patient” is sending statements – ”talking” - to the distant programmed computer and receives a reply on a printer or a display. The ”Eliza” program was, and still is, astonishingly successful. Weizenbaum was even horrified to find that many visitors formed strong emotional bonds with ”her”, and wanted being alone in the room when they ”talked” to Eliza. Some professional psychiatrists were even inclined to let ”Eliza” treat their patients! Even if ”Eliza” uses a kind of faked interaction and in some sense merely ”echoes” the input, albeit in a most clever way, it has on several occasions passed the ”Turing test”!

Although ”Eliza” now is 36 years old – she has also been ”face lifted” on a few occasions – she still continues to captivate those who encounter her for the first time. Obviously Weizenbaum hit some very basic strings in human behavior.
In the early 1960s the first carefully designed system for "Computer-Based Education" was put together at the Urbana Campus of the University of Illinois by a group of creative persons headed by Don Bitzer. The system was called "PLATO" and was probably one of the first timesharing systems used publicly. Although PLATO was a success from the start, it had many shortcomings that later were removed. The system that can be said to be the father of many subsequent learning systems was eventually purchased by Control Data Corporation, and its offspring is now commercially available.

All kinds of interactive simulation programs and systems were also developed in the 1960s and 1970s – not the least for use in different military fields, e.g. war games and flight simulations. They were often hybrid digital and analog systems. Many of the current systems of this kind are extremely sophisticated, very powerful and educational.

With the increased acceptance and use of the Compact Disc (CD) in the late 1970s and early 1980s and the availability of relatively cheap desktop computers, the entertainment industry realized the potential of this combination for interactive games. The field took off with astonishing speed. The market seemed, and still seems, almost limitless. And today we have interactive video games of all kinds – adventure, combat, gambling, driving, management simulation, role playing, sports, strategy, etc., etc.
The "Virtual Biochemistry Laboratory" at the "Nobel e-Museum"

This brings me to the very beginnings of the "Virtual Biochemistry Laboratory" at the Nobel e-Museum. In the late 1990s I did spend many late nights slowly working my way through the great adventure game "MYST". I was most impressed by the excellent graphics; how you could move around in the graphic environment and the clever way clues were introduced to the visitor.

Not long after my MYST experience, Prof. Nils Ringertz, whom I knew from the period when we both were involved in Nobel Committee work at the Royal Academy of Sciences and the Karolinska Institute respectively, asked me if I could think of a way to illustrate chemistry and past Nobel Prizes in Chemistry in his new "Electronic Nobel Museum", as the Nobel e-Museum was then called. He had seen in what direction the electronic media was moving and realized that an Internet based "Nobel Museum" would be a most timely idea. The Nobel name would hopefully make this virtual museum attractive and it could perhaps be made into a rich source of knowledge and information in all Prize areas. He and a small group of dedicated younger coworkers had already made an impressive start despite virtually no external funds.

I was most intrigued by Nils Ringertz’s proposal. After some pondering, I realized that it would be next to impossible to cover the whole of modern chemistry – one had to restrict oneself. Biochemistry seemed like a possible area. Since I had for many years been teaching biophysical chemistry at Lund University, I settled for a "Virtual Biochemistry Laboratory", where a visitor would be able to move around and encounter all kinds of techniques and instruments that were found in real modern labs. And most, if not all, of these techniques and instruments had some connection with a Nobel Prize – not only in Chemistry, but also in Physics and Physiology or Medicine. And of course, I imagined that the visitor could interact and play with these instruments and be able to perform different kinds of "virtual" experiments.

And, to make the lab more exciting for game addicted youngsters, experiments in the lab could perhaps go totally wrong - a poorly balanced ultracentrifuge could, for example, blow to pieces! I had seen the indentations in the walls of the old The Svedberg laboratory at Uppsala where this had actually happened on several occasions.

My first synopsis in 1998 was finally based on the idea that the visitor was presented with a mysterious protein sample – the nature of which he or she had to unravel using the equipment in the virtual biochemistry lab. But one would also be able to learn about the basis of the different methods or instruments, learn about the historical development of the methods and the involvement of different Nobel Laureates, etc. And to guide the visitors through the lab, I had
the idea to introduce a helpful and well-informed lab engineer, named "Virtual Eva" and modeled after a superb lab engineer I had collaborated with for many years at Lund University.

I also thought that the laboratory environment could be based on digital photos of real biochemistry labs, and also that the instruments could be similarly based on digital photos of real ones.

After Nils Ringertz and I had secured funds in 1999 for a "Young Scholars Program" at the Electronic Nobel Museum from the generous "Knut and Alice Wallenberg Foundation", honest work begun. It soon became clear to me that interactive CD games and Internet based interactive biochemistry labs are not playing in the same league, when it comes to communication speed, memory requirements, etc. You can forget pixel-based graphics and thus realistic digitized pictures of real environments. The MYST atmosphere would be lost.

And if I wanted "Virtual Eva" to be able to talk to the visitor, the streaming of her voice had to be synchronized with the pictures – and with Eva’s own bodily movements.

My original idea had also been to have the "Virtual Biochemistry Lab" in three different versions of increasing levels of difficulty. One version – probably the most difficult one to produce - one for kids of the age 8 to 12 or so, one for the age group 14 to 18, and one for college or university students 19 and up. In the end, this became too ambitious and we finally settled for a not-too-well defined "high school/college" age group. We have since found out that the visitors actually cover a fairly wide distribution in ages – there seems to be something there for everyone.

A small group of interactive-production developers and graphic artists were employed and the "VBL Group" after a while consisted of Eskil Janson, Frida Westholm, Mats Danielsson and myself. Also Jan Strandh was involved in the beginning, but he later became involved 100% with other projects in the "Nobel e-Museum" as the official name soon became. Later on Debbie Strand joined the group while Frida moved on to other tasks.

After many trials we finally decided to abandon many of the original ideas of the synopsis. It became too complicated to use a single protein sample in all lab environments. Instead, we decided to let the laboratory consist of a number of rooms, each dedicated to a certain method or technique, for example chromatography, electrophoresis, amino acid sequencing, X-ray diffraction, NMR, etc. The visitors would be able to perform experiments with the different instruments, and interactivity would be built in so that the experimental
conditions could be altered and the outcome changed accordingly. This important aspect of the VBL turned out to be technically very demanding and time consuming to implement.

The lab environment became vector based instead of pixel based. The body movement of our talking ”Virtual Eva” became standardized. It took a long time and considerable help from expert colleagues at Stockholm, Umeå and Linköping (cf Acknowledgements) to design protocols for the interactive experiments. For the production we used ”Shockwave” with Flash graphics and compressed sound. Databases, etc. were written in Perl.

Eva’s lectures, in the beginning, tended to become too long and had to be drastically shortened and subdivided. I learned from an experienced film producer about how to put together ”story boards”, combining text and outlines of the pictures that should go together. After several auditions, we finally found an American girl, temporarily living in Stockholm, who could give us the voice of ”Virtual Eva”.

The complexity of our undertaking gradually dawned upon us, but we learned as we went along. Had we known what we now know, the ”Virtual Biochemistry Lab” could have been produced much quicker and in a much more efficient way. We jokingly said that, ”with proper planning Rome could have been built in one day!”

The product was gradually put together. We had tests on early versions with young students – both Swedish and foreign. They gave us most valuable feedback and we modified accordingly. They all liked the interactive parts – not surprisingly – and we worked them over repeatedly. To make a long story short, we finally put the product on the Internet in May 2001 at the official Nobel web site http://www.nobel.se/chemistry/educational/vbl/index.html.

To date the ”Virtual Biochemistry Lab” has been accessed by some 30,000 visitors. We have also had reviews of the product from many individuals and journals. I had the opportunity to present the virtual lab at a ”National Meeting of the American Chemical Society” at San Diego in April 2001. The official ACS Journal ”Chemical and Engineering News” had a page describing the virtual lab in July, 2001 [”Biochemistry: The Game” in Chem. & Eng. News, 79, p.42 (2001)]. By and large, the reviews have been very encouraging despite some remaining bugs.

But it seems somewhat meaningless to just talk about the Virtual Biochemistry Lab, it feels like trying to describe a piece of music in words. Therefore, I will now give you a live demonstration.
A Tour Through the Virtual Biochemistry Laboratory
When we connect to the VBL Internet address it will take some time to download the data. With a broadband connection it will take only a few seconds, but for visitors with modem and phone connections it may take a minute or two. With the brief attention span of many young visitors in mind we right away challenge the visitor with a number of quizzes while he/she downloads.

**QUIZ — while you wait...**
The total number of Nobel Prize laureates in chemistry between 1901 and 1999 is:

- [ ] 120
- [ ] 133
- [ ] 146

Then we step into the ”Entrance Hall” of the VBL and are faced with a billboard. This allows us either to enter as a guest, for example, if we are a first time visitor or we may decide to log in with a name, real or fictitious. This we may use next time we enter and all our activities the previous visit will be recalled – in particular the problems and challenges we may have solved during the previous lab tour. Challenges? Yes, there are a number of challenges for the interested visitor as we soon will see. But we decide this time to enter as ”Guest”.

Now, we are greeted by our helpful guide “Virtual Eva”, who carries a box or bag and a book under her arms. Now, we may click on these and will learn that the book contains a number of help functions – a glossary of terms, a map of the VBL, possibilities to change different parameters like sound levels, adjust for our level of communication rate, etc. The bag has several compartments, which apparently, are for storing something – perhaps sample tubes of some ”missions”. Missions? We turn around – by using the same approach that was used in ”MYST” – and take a look at the peculiar ”Challenge Board” on one of the walls of the entrance hall.

We may be flabbergasted for a while until we remember that moving the cursor to Eva’s head makes her give you instructions or hints on what to do next. Eventually, we learn that the Challenge Board contains eleven ”Missions” that we may store in our bag and recall when we have entered the relevant room in the lab. Let us store one of the challenges we find on one of the cogwheels – it concerns finding the largest protein molecule in mixture which we have to separate using gel filtration – whatever that is. Hopefully, we will learn this later on in the labs!
The labs? Well, one of the doors of the entrance hall is labeled "Laboratories" so we enter through that. Now we are in a six-cornered "square" – if there is such an "oxymoron" – with six doors to labs dedicated to different methods used in a modern biochemical laboratory.

We may choose any of these and have a look. Let us enter through the door marked "Separation Hall" and go further through the "Chromatography" entrance. Here we learn from Eva that the lab contains equipment for three different kinds of chromatographical experiments – affinity chromatography, gel filtration and ion exchange. But what is "chromatography"? Let us listen to Eva presenting an introductory "lecture" – we click on her head and select this one.

To save memory space in the visitors’ local computer the lectures are downloaded first when we select them. OK, here comes Eva!

Now we may actually do some interactive experimenting!

Due to lack of time at my lecture here, let us assume that we have listened to Eva explaining the basics of a technique called ”gel filtration”. This is in essence based on the use of porous gel particles with pore sizes of the order of a few nanometers. These gel particles will be impenetrable to protein molecules with
diameters exceeding the pore size but penetrated by protein molecules with smaller diameter. Using a column filled with such porous gel particles, you may separate protein molecules with different sizes from each other – the large ones will go straight through the column while small proteins will be retarded since they spend some time diffusing about inside the gel particles.

You may try this method for yourself. Let us take a look at the equipment on the bench that seems to involve a kind of refrigerator with pictures of columns. By clicking on the equipment we have it close by. Eva suggests that we should try to separate a sample by one of the many columns – they apparently have different pore sizes and we will try to find one that gives us optimal separation.

After some trial and error we will find that the column with the largest pores gives us good separation of the proteins in the sample – we can now see that it actually contained four different proteins. The one that comes out first from the column is the largest. You may remember that the “Mission” we selected on the “Challenge Board” told us to choose the largest protein in the separated mixture and put a test tube of his into Eva’s bag. So let us take the red test tube and put it into Eva’s bag. First mission completed we hope – you may check this by returning to the “Challenge Board” and put it to test. A strong applause tells you that you have succeeded.

Lets now take a look at some of the other labs. We go out into the main hall and enter into the NMR laboratory. We are now standing in front of an impressive-looking instrument. What are all these components? We move our cursor to the different parts – here is a superconducting magnet, here a preamplifier for weak signals from the sample in the magnet, and here is a consol that apparently contains some electronic equipment. But what on earth is NMR? We click on Eva’s head and listen for a while to her introductory lecture. Are you any wiser?
NMR is surely among the more advanced biophysical tools used in the VBL. But we do not expect the visitors to become experts after a visit – hopefully, they have become aware of its potential and may like to seek out more information from other sources.

Let us finish our brief tour – it will take many hours to go through the entire lab and perform all the possible experiments – and look at how one can determine the sequence of amino acids in a protein. Don’t be afraid – you will be introduced to this topic very smoothly!

Final Comments
The VBL is a production that certainly may be further developed and improved. The production is still fairly advanced in comparison with other Internet based interactive productions, but we would love to be able to prepare an upgraded and extended version.

One of the reasons why we are unable to do this at present is bluntly the lack of financial resources. It may seem odd for a "museum group" connected with the
Nobel Foundation, however the statutes of the Foundation restricts the use of the capital earnings from its funds. These may only be used for expenses in connection with the Nobel Prizes – for the awards themselves, the outlays in connection with the selection of the Laureates, the central administration and for the Nobel week in Stockholm and Oslo.

As mentioned above, the Virtual Biochemistry Laboratory is part of the "Wallenberg Young Scholars Program" at NeM. The grant financing the implementation of this program is regarded as a one time grant and no additional support is expected. We are currently looking for sponsors among multinational chemical industries that have an interest in the education of young future scientists and engineers.

Addendum
During the proofreading of this article, and shortly after the end of Nobel Symposium 120, the Director of the Nobel e-Museum, Nils Ringertz, unexpectedly and sadly passed away. His enthusiastic leadership, never failing personal involvement and steadfast support of all his coworkers were pivotal ingredients that have made the NeM a successful undertaking. I feel continuing gratitude to him for the opportunity to work with him during the past three years and for the experience of his encouragement and friendship.

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The voice of our “Virtual Eva” was contributed by Kara Bowden, and she patiently worked on the pronunciation of the many technical terms in the text. Urban Frank introduced me to the concept of “story boards” and gave us good advice on how to combine pictures and text in the VBL.

Finally, my warmest thanks to the young, dedicated and cheerful NeM staff, who have been most supportive and made our daily endeavors very enjoyable!