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ABSTRACT

The purpose of this study was to evaluate The Student Genome Project, an experiment in web-based genetics education. Over a two-year period, a team from New York University worked with a biology teacher and 33 high school students (N=33), and a middle school science teacher and a class of students (N=21) to develop a World Wide Web site intended to enable middle and secondary school students to learn the principles of molecular genetics in fun and engaging ways. A second major aspect of the project involved both the high school and middle school students working in pairs on genetics research projects by gathering survey data in their schools and data on the molecular genetics of their topic from the World Wide Web. Interactive web pages and a webboard were used to guide and mentor students during their research projects. Data sources included genetics literacy surveys, technology literacy surveys, postings on the webboard, and interviews with teachers and students. Important factors involved in the design and implementation of the World Wide Web site were identified and used to develop a theoretical model of student-centered web-based science education resources. (Contains 37 references, 6 tables and 2 figures.) (Author/DDR)

A Model for the Development of Web-Based, Student-Centered, Science Education Resources

by
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A Model for the Development of Web-Based, Student-Centered, Science Education Resources.

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The purpose of this study was to evaluate The Student Genome Project, an experiment in web-based genetics education. Over a two year period, a team from New York University worked with a biology teacher and thirty-three high school students and a middle science teacher and her class of twenty-one middle school students to develop a web site intended to enable middle- and secondary school students to learn the principles of molecular genetics in fun and engaging ways. A second major aspect of the project involved both the high school and middle school students working in pairs on genetics research projects by gathering survey data in their schools and data on the molecular genetics of their topic from the Web. Interactive web pages and a webboard were used to guide and mentor students during their research projects. At the end of year two, all of the science fair projects will be exhibited in school science fairs and also in an online interactive science fair. The online interactive science fair will be held in a collaborative virtual learning environment built upon a webbed MOO (Multi User Dimension Object Oriented).

Genetics literacy surveys and technology literacy surveys were given to all of the students before and after the project was completed. Other data collected consisted of the students' postings on a webboard, and interviews conducted with the secondary teachers and students. Important factors involved in design and implementation of the web site were identified and these were used to develop a theoretical model of student-centered web-based science education resources. The model is now being used to develop an instrument to analyze and compare the characteristics of educational web sites.

Significance:

There has been a tremendous amount of frenzied activity on the World Wide Web in the past few years. New web sites spring up every day while others vanish just as rapidly. It is very important to look closely at the process of web site creation and not only at the end-product, the web pages. There are many important differences between traditional methods of publishing science education materials and publishing on the World Wide Web. The characteristics of paper and electronic media also differ substantially. The whole experience of accessing web sites has a substantial effect on what is, and is not possible educationally.

Surfing the World Wide Web can be very time-consuming and may not always be educationally productive. Presently there is little published research on the educational effectiveness of the World Wide Web. This study involved a detailed evaluation of a web-based, student-centered, science education resource in order to identify the factors that contribute to, and those that do not lead to an effective educational experience. Once the positive and negative factors were identified these were used to develop a theoretical model which could be used to enhance educational web site development.

Theoretical underpinnings:

Constructivist theory was used to frame this study in that it was deemed important to analyze the process of educational web site development, and not the just the final product. It is very possible that factors related to web site design and construction might limit the educational potential of the World Wide Web. Examples of factors are the importance of bandwidth, the dependence of educators on programmers, artists, and graphics designers. Other factors, such as the ability to allow exploration of three- dimensional environments, collaboration in multi-user environments, and interactive multimedia, may make very new forms of learning possible. Finally web-based communication tools can be used to allow several different forms of learning to take place, such as modeling (Bandura, 1971) by novices of experts in a form of cognitive apprenticeship, interaction in a multiple electronic zone of proximal development (Murfin, 1994), and project-based science learning (Krajcik, Blumenfeld, Soloway, 1994; Blumenfeld et al. 1991.)

The computer and the resources available on the World Wide Web are regarded here as teaching and learning tools, from which educators and students may pick and choose. Unfortunately, the tools available may not always match the educational needs of students, and therefore, educators and students must be involved in the process of development of educational web sites. Due to the rapidly changing nature of technology, learning experiences that are "self-directed" and that involve "just-in-time training" are essential (Khan, 1997, p. 27). The "just-in-time" concept argues that students should learn a concept at the time they need it and not before. Incorporating this into web-based instruction and learning could prove a very definite advantage since software applications, computer programming languages, web authoring tools etc. can become totally obsolete in the space of six months. The explosion of information occurring in all of the sciences makes it virtually impossible for teachers and students to learn the basics and to keep up-to-date with recent advances. In fact, the basics may also be changing. Skills such as information handling and analysis and the navigation of vast, complex databases were not as critical in the past as they are now. There is a tremendous glut of information on the World Wide Web. Clifford Stoll (1995) in his book *Silicon Snake Oil*, eloquently described the obstacles that technology and the Web place in the path of education. Much of the information on the World Wide Web is garbage and still more is far beyond the cognitive reach of secondary school students and teachers. A very useful function performed by the educational web site designer is to filter and translate information. The process of translating or converting information into forms that will enable students to construct useful knowledge and understanding may require new pedagogical techniques, learning environments and experiences, and innovative thinking in web-site development.

Educators need to determine the characteristics of the students, the ways in which students learn, and the different technological tools available, and then try to match these tools with the desired mode/s of learning, or if necessary create new tools. Once learning objectives are specified, educational experiences can be arranged that will enable all students to accomplish the educational goals. Throughout the entire process, a strong focus should be maintained on the characteristics and needs of the learners. A few important characteristics that vary among learners are cultural background, life experiences, preferred learning styles and sensory modalities. The needs of today's students are many and include the following: social, psychological, physical, and intellectual. There are many ways in which students learn, and some may be more productive than others when experienced on the World Wide Web.

Design:

A case study of the Student Genome Project http://www.cat.nyu.edu/sgp was carried out over a one year period. The Student Genome Project is a web-based science education resource developed by a team of science educators, scientists, and students. Data were collected at the beginning, during and at the end of the project. The data consisted of interviews, a genetics literacy survey, an attitudes towards genetics survey, a technology survey, and postings on a webboard. The data were analyzed in order to identify important factors that influenced the web site design and construction processes. A theoretical model was then constructed that illustrates the effect of the various factors on the desired educational outcomes, aspects of scientific literacy such as learning basic principles of genetics and becoming technology literate.

Procedures:

In the Fall of 1996 a multidisciplinary team of science educators, scientists, and various technology experts was assembled. Overall educational goals were set and a one-year plan was developed. Tasks were assigned to individual team members and subgroups were formed. Data was collected continuously during the project by various means. All instruments cited in this paper may be found at the following web site:

http://www.nyu.edu/education/scied/narst98. Once the data were collected and analyzed, important factors were identified, and used to create the theoretical model.

Data analysis:

The genetics literacy survey and attitudes towards genetics survey were analyzed using the Statistical Package for the Social Sciences. Interviews were tape recorded, transcribed and then subjected to a content analysis. Messages from the webboard were sorted chronologically and categorized.

Findings:

Student Interviews:

Seventeen high school students out of a group of thirty-four in a Biology Honors class from a school in East Harlem, New York City were interviewed at the end of the 1996 school year. All seventeen had taken part in The Student Genome Project for one school year. During the project the students worked on science fair projects on topics related to human genetics. The students had limited access to a computer lab where they were able to use email, search the web, and create web pages describing their projects. The students worked in pairs and their web pages can be seen at http://www.cat.nyu.edu/sgp/projects/index.html. The topics of their projects ranged from HIV, Alzheimer's disease, Parkinson's Disease, the X chromosome, the Y chromosome, the Human Genome Project, Down's Syndrome, hemophilia, Tourette's Syndrome, glaucoma, and leukemia.

Responses to Genetics-related questions

What is a gene? On this question there were no entirely correct responses. Table 1 below contains a summary of the results to this question.

Table 1. Responses by high school students to the question "What is a gene?" n=17.

Concept	Number of responses
Parents mentioned	3
DNA mentioned	6
Chromosomes mentioned	6
Information	5
Hair, eye color	2
Analogy used	4
Traits, characteristics	3
Confusion with chromosomes	4

It was gratifying to see that many students understood that genes are made up of DNA and that they carry information. There was some confusion between genes and chromosomes as evidenced by the following responses:

<u>**Student #2:**</u> "A gene (pause) okay wait chromosomes are made up genes. Genes are made up of chromosomes. Oh, no chromosomes are made up of genes, I am not sure."

<u>**Student #6:**</u> "A gene is a bunch of chromosomes put together to make a character a characteristic of yourself. That's all"

Analogies were used frequently by the students and this seems to help make abstract topics more concrete and understandable. Below is an analogy related by one of the students:

<u>**Student #3**</u>: "A gene is a (umm) like a piece of information on a chromosome. Yeah, its like a page in a book. The book is a chromosome and a page is a gene."

Many of the students' explanations were very imprecise. None mentioned that the DNA sequence of a gene determines the sequence of amino acids in a protein in their answer. The only examples of inherited traits given were those of hair and eye color.

"<u>Describe the structure of the DNA molecule</u>"

Table 2 below contains a summary of the responses to this question.

Table 2. Summary of responses on the structure of DNA

Category	**Number of responses**
Double helix mentioned	10
Nucleotides mentioned	4
Analogies used	19
Incorrect description of helix shape	3
Odd ideas	6
Description of composition	7
Incorrect base matching	8

The students seemed to have partial knowledge of the structure of DNA. The fact that DNA has a double helix structure, is made up of four different nitrogenous bases, and contains sugar and phosphate was well known by the students. About half of the students correctly described the pairing of the nitrogenous bases. The students frequently used analogies such as "Like the statue of liberty have you ever been up there to the crown it twists around," and "a twisted ladder." Many students had very odd ideas about the shape of the DNA molecule such as

Student #3: "Its swirly, it goes in a circle, not a circle, like a twisted circle"

There seemed to be confusion over the difference between circle and helix shapes.

Another problem noted was the carelessness and imprecise language used in the students' explanations. Both can be seen in the following examples:

Student #1: Um. It's a double helix and has two strands and has nucleotides ATCG and match up with each other. So then it kind of spins around and as soon as it spins and gets smaller and smaller but if you unwind it gets greater, it gets bigger and you can see what matches with what.

Student #4: "The structure of a DNA molecule is there 4 different types that they have 3 components each phosphate sugar & base. And there a 4 different bases, like Adenine, Thymine, Guanine and Cytosine and in complete for transcription."

It would have been interesting to follow-up on this question with Student #1 to find out the origin of the visual imagery in the second sentence. Computer or video animations involving the DNA molecule may be the root of this phenomenon. If this is true, then computer animation and graphics should be used very carefully in order to avoid creating misconceptions.

Another very common misconception was confusion between DNA and chromosomes. Perhaps a systematic introduction to this topic that unambiguously displayed the relationships between the "increasingly complex microworlds" (Burton, Brown, & Fisscher, 1984) involved would help avoid this misconception. Research into various graphical methods of presenting the relationship between genes, chromosomes, and DNA might be very useful. Finally, the use of concept maps could help students reinforce the relationships between the concepts.

Question 11. Briefly describe how DNA is sequenced.

All students answered this question very poorly. Most answers repeated a description of the structure and composition of DNA and the listing of the nitrogenous bases. Speculation, fanciful ideas, and careless and imprecise descriptions abounded such as

Student #4: "How DNA is sequenced, well what they do is they extract DNA from the cell and they inject it into these cell and they inject it into these gel-slabs and they do some electro and they electrocute it over night. Like different bands will show up. You get the, the different like."

and

Student #10: "They probably narrowed the bases to see, because well every person has a different gene and chromosome, so they probably paired it up to see if it matches his."

and

Student #17: "Well I think what to do is you give people a drug. I think that's way DNA will it, ever person has a different DNA makeup. If it was in his matches or anything, like you know it could be a possibility that you know that they got the right person, that's possible."

Question 12 - How do scientists identify disease-causing genes?

The most common response was to use karyotyping, where the chromosomes in a cell are photographed during cell division, and the images sorted and counted. A small number of students described its use correctly in the identification of Down's Syndrome which is caused by an extra chromosome. A misconception encountered in some students was the idea that genes could be karyotyped. It is possible that the confusion between genes and chromosomes is causing the problem or it could be a fundamental misunderstanding of the process of karyotyping.

Several mentioned that one would look for mutations although few details were given on how to do this. One student had the beginnings of a correct idea where a normal person's genes would be compared with an abnormal person's genes. Only one student mentioned looking at the parents and none discussed investigating a family tree or pedigree in order to identify disease genes. Overall, the students seem to have some very vague ideas, such as "looking into the chromosomes and DNA," etc., on this topic. One example, Down's syndrome and the use of a karyotype seemed to stick in their mind, but other than that, their knowledge in this area was very shallow.

Question 13 - What is the cause of sickle-cell anemia?

Sickle cell anemia was the focus of the first year of this project and the students engaged in several different learning experiences related to this topic. The Co-Director of the Sickle Cell Institute of Montefiore Hospital gave a presentation on the clinical aspects and causes of the disease. The students experienced interactive multimedia tutorials on this topic, and also visited a biology lab at NYU for a session on DNA structure. Almost all of the students correctly stated that the disease is caused by abnormal hemoglobin, and that the shape of the red blood cells was distorted. Analogies were used to describe the shape of the affected cells, e.g. half-moon, crescent moon, etc. A few students incorrectly referred to "blood cells" instead of red blood cells and this is another example of the carelessness and imprecise language that characterized many of the student responses. It seems that the students either do not understand important concepts or that they are making assumptions that the interviewer "knows what they mean."

Only four students mentioned that the cause was a mutation, with two specifying this as a point mutation, i.e.,

> **Student #7:** "Um it's a gene point mutation on chromosome. I don't know the chromosome. This is the gene or chromosome that causes the red blood cells to, they don't carry the oxygen."

The following student alluded to the mutation, but again got it wrong since the mutation is a substitution, i.e. the sixth codon in the Beta globin gene of hemoglobin changes from GAG to GTG and not a deletion of a base (Micklos, Freyer, 1990):

> **Student #17:** "The sickle cell anemia is a condition where the red blood cells are not fully formed, there like sickle cell there like like a simple and usually caused by a missing base, it usually caused by a missing base in the DNA molecule. And one missing base will cause that and a person can have sickle cell anemia or like ..."

None of the students fully described the cause of the disease (i.e. a single base substitution in the DNA molecule leads to a substitution of one amino acid for another in the beta chain of the hemoglobin molecule). This mutation is what causes the hemoglobin molecule to change shape at low oxygen concentrations and the characteristic sickle shape of the red blood cells results.

Most of the responses were descriptions of clinical details of the disease. One common mistake was the idea that the sickled cells were sharp and that they would cut and tear veins. The students did not seem to know the difference between capillaries and veins, and that the problem lies in the sickled red blood cells blocking the smaller blood vessels, i.e., the capillaries. Misconceptions on related topics emerged in the answers, such as the one illustrated in the following quote, that clotting is bad for you:

> **Student #6:** So you know you don't have enough hemoglobin in your blood and blood clotting is bad for you.

This is definitely incorrect and needs to be qualified as blood clotting is not always bad, in fact, a person suffering from hemophilia would just love their blood to clot.

Only two students said that they did not know the answer to this question. Most of the students gave answers to all of the questions and many were incorrect or imprecise. Very few actually admitted they did not know the answer. It is very probable that they did not know that they did not know the answer. How does one know when one does NOT know? It seems that this is a critical skill that students need to learn. It is also possible that this skill is context-dependent, i.e. it may be easier to realize ignorance in certain subject areas and situations than in others (Sykes,1996).

Question 14 - Briefly describe the Human Genome Project and its importance.

Almost all of the students realized that the Human Genome Project (HGP) was related to making a map of human DNA and chromosomes. However, beyond this there was little of substance in the answers. None actually defined the term "genome," or mentioned that the sequencing and mapping of DNA is also taking place with the DNA from other organisms and not just humans. The most common response as to the importance of the HGP was that this project was trying to find the causes of hereditary disease by locating mutations, and also discovering cures for these diseases. One student stated that the HGP would help to "trace past deaths," an obvious reference to the use of DNA fingerprinting in forensics. The confusion between genes and chromosomes pops up again as seen in this response:

Student #3: "The Human Genome Project, its importance is to umm, they look into your cells and they find the chromosomes that make um your body's genes. And they try to find what genes make to what. And their goals is to find cures for disease that are hereditary or what. "

Technology and research-related questions

Question 6 – Where did you find information on your research topic?

All of the students obtained information for their research projects from the Internet. The students using the Internet reported that they received information from hospitals, doctors, and universities. Some obtained pamphlets and other material from sources such as the Glaucoma Foundation in San Francisco delivered via U.S. mail. About half of the students reported using books and/or encyclopedias from the library. One group utilized microfilms.

Question 7 How did using the computer and world wide web help you with your research?

The responses to this question were very revealing. Many of the students stated that they preferred using the web instead of the library. Among others, the reasons given were that the web takes less time, is more convenient, gives a greater volume of information, more current information, more specific information, and that information was easier to find. Some students obtained information directly from local doctors, doctors overseas and hospitals via the web and email. The students specifically mentioned that information from the web was more current than that found in books or encyclopedias, especially on topics related to human genetics such as in the following quotes:

Student #14: "You get a book yeah that's ten years old and stuff they don't have like stuff the Human Genome Project."

Student #6: "All of it was recent. Most of it the stuff that I got from the library was all old articles and old books, so most of that stuff that stuff was recent."

Student #9: "Well the information was easy to find, going to the library you'd had to look all around for the book. It's a better way, so you don't have to worry about being late with the book."

It is true that there was a substantial amount of quality information on the topics that the students were investigating in their research projects. However, one would hope that the students would not abandon libraries since they are an extremely valuable source of high quality information whereas much of the material on the web is of dubious quality due to it being self-published and unedited.

Question 8 – What difficulties did you have with the computer and the world wide web?

The difficulties reported by the students were mainly hardware and software related. Among others described were stale, non-functioning links, hardware malfunctions, too many people and not enough computers in the labs, computer freezing up, failure to connect to web sites, taking a long time to connect, and waiting. An interesting comment from one student was that the promises of some web pages were frequently not realized and were thus a form of "false advertising."

Student #7: " Um a lot of stuff that sounded like we needed it it but it wasn't really necessary."

Interviewer: False advertising.

Student #7: "Yeah it was like they had something that sounded good that we could have used and then when we went into it, it was dragging on and on and on. It was too long we didn't need it. That took a lot of time."

Other complaints involved not knowing what to do, having to remember and write down URL's, making typing mistakes, and finding correct addresses on the Web. A small number of students stated that they had no difficulties at all.

Genetics literacy survey:

A forty-item multiple-choice survey was administered to assess the student participants' (n=27) understanding of basic genetics concepts. This was conducted while the students were working on their research projects and concurrently discussing genetics in their science class. Topics included were the central dogma (DNA as hereditary material), Mendel's laws, pedigree analysis, sex determination, sex-linkage, and test crosses. An item analysis was carried out on the genetics literacy instrument by calculating the Difficulty and Discrimination Indices. The results of the item analysis can be seen in Tables 3, 4 and 5.

Table 3. Difficulty Index and Discriminating Power of Items on Genetics Literacy Survey,1996 (Gay,1987)

Question	Difficulty Index	Discriminating Power	Question	Difficulty Index	Discriminating Power
1	0.89	0.22	21	0.89	0.22
2	0.72	0.33	22	0.17	0.11
3	0.89	0.22	23	0.78	0.44
4	0.44	0.22	24	0.78	0.22
5	0.78	0	25	0.28	0.11
6	0.83	0.11	26	0.89	0.22
7	0.83	0.11	27	0.44	0.44
8	0.67	0.67	28	0.33	0.44
9	0.78	0.44	29	0.5	0.56
10	0.89	0.22	30	0.28	0.11
11	0.61	0.11	31	0.39	0.33
12	0.89	0.22	32	0.39	-0.11
13	0.33	0.22	33	0.67	0.22
14	0.17	0.33	34	0.78	0.22
15	0.67	0.44	35	0.78	0.22
16	0.89	0.22	36	0.56	0.67
17	0.78	0.22	37	0.56	0.44
18	0.56	-0.22	38	0.61	0.33
19	0.39	0.11	39	0.5	0.33
20	0.5	0.56	40	0.67	0.22

The survey discriminated well between the highest 25% and the lowest 25% of students who answered the survey (n=27) as can be seen in Table 4. The ten questions that did not discriminate well were examined carefully . 7 out of the 10 items in question showed that the lowest 25% performed better than the highest 25%. There are several possible reasons for this. One reason may be that students were not taught the required concept in class. Other items used terminology that may have been foreign to the students (#22 uses the term "pollywog" rather than "tadpole"), or that certain symbols used in diagrams may have confused students (#11 used a different notation for sex-linkage). A possible reason why some questions did not discriminate well was because cerain concepts (such as mature red blood cells lacking a nucleus) were learned by the students in a context other than genetics (#25). The interactive multimedia on the SGP website did not cover some of these concepts (#5,6,and 7) and students did not have adequate time to access the necessary learning experiences available on the SGP website.

Only one student correctly answered question 14. One plausible explanation of the poor performance on this item could be the students' difficulty in understanding terms like "non-sex chromosome" and "gamete". The manner in which the question was phrased could also have resulted in comprehension problems for students not familiar with the language of genetics.

The next three questions (12 to 14) refer to the following information.

In mice there are a total of 40 chromosomes in each body cell and sex determination is controlled in the same way as in man. That is, a sex chromosome complement of XY is found in normal males and the XX complement determines female characteristics.

14. How many non-sex chromosomes are present in a mouse gamete?

a. 18 b. 19 c. 20 d. 38

The reanalysis of the patterns of responses suggest that some items that did not discriminate well should be reworded, diagrams modified and some questions may need to be eliminated and replaced.

Table 4. Discriminating Power of Items on Genetics Literacy Survey, 1996 (Gay, 1987)

Level of Discrimination	Discriminating Power Index	Number of Test items	Percentage of Test Items
Good	0.40 or better	10	25%
Satisfactory	0.20 to 0.39	20	50%
Poor	0.0 to 0.19	10	25%

Table 5 contains the Difficulty Level of each survey item. As can be seen, there were no items classified as very difficult and most items were in the very easy or fairly difficult category. The function of the genetics literacy survey was to determine whether students understood basic genetics concepts. It was not constructed as a "power test" that would be a measure of speed in test-taking. It was also deemed very important that the test not discourage students from becoming interested in genetics.

Table 5. Index of Difficulty of Items on the Genetics Literacy Survey, 1996 (Gay, 1987)

Level of Difficulty	Difficulty Index	Number of Test Items	Percentage of Test Items
Very Easy	0.85 - 1.00	6	15%
Fairly Easy	0.50 - 0.84	23	57.50%
Fairly Difficult	0.16 - 0.49	12	27.50%
Very Difficult	0.00 - 0.15	0	0.00%

Based on the data collected, the survey was revised this year to include some open-ended questions:

> Projects such as the Human Genome Project are helping people gain more knowledge about human genes. What possible uses (both good and bad) could result from this knowledge?
>
> When cells in the human body reach a certain size, they divide and produce two daughter cells. Do all cells in the human body divide in the same manner? Explain your answer.
>
> Give five (5) characteristics you possess that you believe you inherited from your parents.

This type of questioning encourages the broader and deeper range of diverse responses (Carin, 1997) that is necessary to understand the extent of student learning. Teachers rarely have the opportunity to hear enough of what students think to recognize when the information that is offered by students is only a surface retelling for school purposes (Brown, et al, 1996). Answers to these questions may be difficult to quantify but are a source of important data on higher order processes and skills that involve analysis, synthesis and evaluation.

Attitudes Towards Genetics Survey Data

Another important aspect that was considered in evaluating student learning in this study was examining the attitudes of students towards genetics. This survey focused on how students (n=27) perceived the recent developments in the fields of genetics and biotechnology such as cloning and the Human Genome Project (HGP). Student responses to thirteen statements were measured using a four-point Likert scale.

Data collected showed that a majority of students support the HGP (77.8%).

5. I fully support the Human Genome Project.

Strongly Agree	Agree	Disagree	Strongly Disagree

Roughly equal numbers agreed (59%) and disagreed (41%) about the possible advantages of current research in the field of genetics.

11. The benefits of new research in molecular genetics, far outweigh the potential dangers.

Strongly Agree	Agree	Disagree	Strongly Disagree

Students were clearly against the idea of cloning animals (56%) and even more against the cloning of human beings (85%)

8. Cloning of animals is a good thing.

Strongly Agree	Agree	Disagree	Strongly Disagree

9. I see nothing wrong with cloning human beings.

Strongly Agree	Agree	Disagree	Strongly Disagree

Roughly half of the students believed that intelligence is an inherited trait (54% agree), but that behavior isn't (60% disagree).

12. Intelligence is something we inherit in our genes.

Strongly Agree	Agree	Disagree	Strongly Disagree

13. Most human behavior is determined by genes.

Strongly Agree	Agree	Disagree	Strongly Disagree

The influence of popular culture and mass media is clearly reflected in the patterns of their responses. An example of this is the question dealing with the cloning of humans where 85% of the students were against cloning of humans. The students' opinions were greatly skewed on statements that dealt with clear-cut and well-publicized issues such as cloning and the inheritance of intellectual capacity. Topics that were controversial and still heavily debated, such as weighing the consequences of the Human Genome Project, elicited a polarized response from students, with an almost even split of opinions within the class.

The preconceptions that students hold on particular concepts and the opinions they have on issues can greatly influence how students learn. Recognizing and identifying these student-constructed ideas is valuable in the areas of instruction and assessment. An important question that emerges from this is how this understanding should be used to maximize student learning. Research has shown that children's alternative or "naïve" conceptions are very difficult to modify and do persist despite the new knowledge teachers attempt to introduce in class (Driver, 1988). How teachers choose to remodel knowledge can be achieved in a variety of ways, from changing an existing concept, adding on to current knowledge or replacing misconceptions or a combination of methods.

Analysis of Webboard messages:

The high school students worked on genetics-related research projects and were encouraged to post their topics and subsequent developments in their research. Project team members at NYU could then post messages replying to questions from students, leading them to information pertinent to their research, and giving them words of encouragement as they worked on their projects. The web board was most active from the first week of February to mid-March, when students were most involved in constructing their outlines, collecting data and preparing for the science fair in May.

Data from the webboard messages are a source of important information about the value of asynchronous means of communication. The postings indicate that students were enthusiastic about being able to communicate with mentors that were experts in various aspects of their projects. With the limited time (about 15 minutes per week) that students spent on line during class sessions, they looked forward to checking the webboard for replies to their messages or to post new messages, which were often typed off-line and saved on disk before being uploaded on the webboard.

Mentors' responses were generally of three types: 1) supplying direct answers to questions students had posted, 2) providing encouragement and motivation to students, and 3) listing possible webpages and resources that might lead students to more information relating to their research topic. Below are some examples of such exchanges (Each message has been labeled to indicate whether it was posted by a student or a mentor. Mentors' responses are italicized).

Furnishing answers to students' queries made up about 15% of the responses. It is difficult to ascertain the implications of this type of response without considering the nature of the student-mentor relationship and the history of the interactions between both parties. Given the fact that students did not have much time online, it is only natural that mentors attempt more direct means of addressing the students' questions, thus providing them with some "solutions" to their problems, as shown in the exchange below:

STUDENT

Questions:
1. When was this procedure put to test and how many years did the research take before putting this procedure to

practice?
2.How does Amniocentesis detect a chromosal error, how does it look like?
3. What is amniotic Fluid and what does it contain?

MENTOR
Amniocentesis is the removal of amniotic fluid (the liquid that bathes the fetus) from the amniotic sac, the cells in the fluid are largely from the amniotic membrane and some fetal skin cells. Since they are not actively growing they need to be cultured for 7-14 days. After that the cells are broken to release the chromosomes which are stained with various techniques for visualization. The chromosomes are counted and matched up in 2 pairs, and then examined for evidence of missing pieces or extra pieces. The most common reason for chromosome analysis is to look for evidence of trisomy-three copies of a chromosome instead of the expected two. The trisomies 13,18 (Edward's syndrome) and 21 (Down syndrome) are the most common.

Other samples show evidence that this type of reply from adults enabled students to progress in their research by providing them with necessary assistance that would help them with understandings just beyond their reach (Vygotsky, 1992). This function is also very true regarding the second type of response, which mainly served to encourage and motivate students. Below is a sample of this type of message that made up about 25% of the adult responses on the webboard.

STUDENT
Parkinson's disease is a disorder of the nervous system that slows the progress of reactions. We would like to explore the role of genetic factors in the development of this disease.

MENTOR
HOW WOULD YOU START TO INVESTIGATE THE POSSIBILITY THAT THERE IS A GENETIC FACTOR IN THIS DISEASE?

STUDENT
To find out how a patient would have inherited Parkinson's from a relative, one might draw up a family tree of the different generations in the family and track down those in the family who had the disease. This would help in finding out if the disease is inherited.
Questions
Are there any differences in parkinson victims among racial groups?If so, which group is affected most by parkinson's and why?Is ther a difference in parkinson victims among age groups?

MENTOR
GOOD QUESTION !

STUDENT
The population of americans that are diagnosed with parkinson's each year is 50,000.Studies show that african-americans and asians are less likely to get parkinson's than whites.The reason for this is unknown,but all people have a probability of developing the disease.This disease is a disease of the late middle age,most people over the age of 50 suffer from parkinson's.

MENTOR
HAVE YOU DONE ANY PROGRESS ? CAN YOU POST IT ON THE WEB PAGE ?

The third type of response that made up the majority of adult messages on the webboard provided students with listings of possible websites and other resources that would be helpful in their research. In contrast to simply supplying a direct reply to a student's question, this type of response attempted to direct students in finding answers to their problems. The following posting is an example of this type of approach.

STUDENT
We are students from Manhattan Center for Science and Mathematics High School and we are involved in the Student Genome Project. We are making a research paper on sickle cell anemia disease for our school.s science fair. We haven t done many yet but here s our thesis statement: The sickle cell anemia disease is

produced by an inherited genetic mutation resulting in a low production of hemoglobin, thus causing Red Blood cells not to carry enough oxygen.

MENTOR
Here is a good web site on sickle cell anemia. Click below to access it:

- Sickle cell web site

A convenient function of the webboard allows a user to post links directly on the webboard. This capability has several advantages: 1) a record of useful links is maintained; 2) the links provide greater accessibility to websites. This makes it is easier for new users since they do not have to write down, remember, or type in long and complex URLs. One of the most common problems on the web is typing in bad URL's. Many novices do not realize that URLs reflect paths to files on computer systems using the Unix operating system where upper and lower case letters are very important.

Another interesting aspect of asynchronous communication is revealed in the webboard messages of students that were typically carefully worded and well-constructed. This was due to the fact that given the limited time students spent on line each week, it was crucial to maximize their time. This meant composing their messages off line and saving them on disk while waiting for their turn on the computer connected to the network.

STUDENT
Questions: What other things can we include in our outline/ paper that can make it more interesting and more presentable?

In what ways can we present this project so that people would find an interest in this syndrome?
Can you tell us where we could get a video of people with this syndrome so that we can use it in our presentation.
Do you know of anyone with this disease, and if so may we interview them on camera?

There are several advantages to this type of "advanced preparation" on the part of students. It helped them think over their questions thoroughly before posting them in addition to teaching them to organize their ideas and share limited resources with their peers. A clear disadvantage of this method, though, is the lack of spontaneity in their messages and replies to mentors' messages which is evident in most correspondence of young people in this age group.

When students typed messages directly onto the webboard, they were often shorter and lacked the organization demonstrated in messages composed off line. This is shown by the sample below, which shows a follow-up message posted by the same students in the previous example.

STUDENT

thankyou very much for your answer but you didn't answer # 4
Tourette's Syndrome;

THANKYOU ONCE AGAIN.

The brevity and lack of content in this message illustrates how important adequate time for careful thought and reflection is in communicating asynchronously. This is not only true in terms of webboard communication but in other forms of asynchronous communication such as electronic mail. The convenience of computer mediated communication (CMC) can also give rise to communication problems brought about by unnecessary brevity, careless use of language, and other grammatical errors. In terms of educational research, this can give rise to problems in accurately assessing student learning using the webboards and other forms of CMC. These could include human -computer interface interference, various environmental constraints (such as time limitations and computer anxiety), and general miscommunication which would lead to incorrect analysis of how much student learning has taken place.

Given the limitations of this study (namely the limited time on-line for students and the relatively small sample of messages collected due in part to the mentor-student ratio) it is difficult to ascertain any trends observed from the postings on the SGP webboard. It would be interesting to be able to gather data from a larger sample of students to compare the quality of messages posted on the webboard on-line and off-line. The quality of interaction between students and their mentors could be measured using criteria such as the length of messages, the number of grammatical and typographic errors, content of messages, and coherence of ideas.

Technology Survey.

Another important factor that could influence the effectiveness of the SGP web site would be the technology skills students were equipped with. Knowing the students' background and familiarity with computers is valuable in planning and implementing any web-based instruction program. During the second-year of the project, a technology survey was constructed to gauge several aspects of the students' technology literacy before and after the school year. The survey included questions that dealt with the user's access to computers, familiarity with different platforms, knowledge of various software applications, and use of different modes of CMC. Students were also asked to identify their expectations about the use of technology in science classes and their assessment of the importance of technology in their classes.

This is part of the continuous program assessment of the Student Genome Project, that in conjunction with the various other surveys would provide feedback on the processes and effects of the project to directly benefit program improvement and evaluation (NRC/NAS, 1996).

Important factors contributing to successful educational web site design.

A web site should be designed with specific learners in mind, and not as a generic product. There should be a strong focus on the learner, and on a theme or topic. The web site should have strong links to the learners' curriculum. The learners must be integrated into the design process. The role of project director is that of facilitator, and the director and entire development team must all learn continuously about each other's specialties. Most importantly the traditional boundaries between the disciplines need to be broken down.

A multidisciplinary team is essential for the development of educational web sites. Many of the technological skills required for the task are so highly specialized that it is rare to find one individual who is skilled in all of them. A good example on Student Genome Project team was the developer of 3D VRML worlds. This individual needed artistic and drawing skills, along with a knowledge of computer programming and experience working with Silicon Graphics workstations, 3D software and other specialized applications. The developers of the Student Genome Project Shockwave movies used completely different software, e.g. Macromedia Director, Adobe Photoshop, SoundEdit, DeBabelizer, and others. Neither the VRML or Shockwave developers were very familiar with each other's specialty. However, these two still needed the services of science content specialists and science education experts to design and construct the desired learning experiences.

A comparison of student-centered science education web sites with other types of science education web sites.

One important characteristic of educational web sites is the target audience of the site. During the design of an educational web site this must always be considered. Some web sites are general purpose and not designed with children or adults in mind. Some are sites are aimed at teachers, e.g. the web site of the National Science Teachers Association http://www.nsta.org, The ERIC web site http://www.ericse.org/science.html, and the Eisenhower National Clearinghouse for Math and Science Education, http://www.enc.org. Others are aimed at even more narrow audiences such as the NARST web site at http://science.cc.uwf.edu/narst/narst.html that mainly serves Science Education researchers. A very good example of a student-centered web site is "MaMaMedia" http://www.mamamedia.com, a site that was recently developed by Idit Harel, Ph.D. and based on the work of Professor Seymour Papert, the co-founder of MIT's Media lab. This site was developed for young children between the ages of 5 to 10 years as one can see by the reading level, and level of the content presented, although many of its exciting and innovative features might appeal to older children and adults. The term Web-Based Instruction (WBI) has become very popular (Khan, 1997) and it's main goal should be the educationally effective design and maintenance of a student-centered web site. Web-based instruction should facilitate Web-Based Learning (WBL) by students. These investigators propose that web sites that are specifically tailored to students will be more effective learning environments than web sites developed for generic audiences.

The unit of analysis for research into web sites is problematic. Many individual web pages contain very little information other than pictures, animations or a few words while other web pages are filled with text. Some web sites are very extensive and consist of hundreds, even thousands of individual pages while others are highly focused and are made up of a few pages. There are web sites that contain various areas that are devoted to students, others for teachers, etc. Many of the same measures that have been applied to science textbooks could also be used in the evaluation of web sites, e.g. reading level, portrayal of males, females, and various ethnic groups, etc. However, web sites have many features that static text does not. For example, all the different methods of making web pages more interactive, Java applets, ActiveX, Javascript, cgi scripts, VRML worlds, the use of sound and animation, and interactive multimedia such as Shockwave movies could have important effects on the learning of science. In addition, the characteristics of the human-computer interface, i.e., use of a QUERTY keyboard, the use of a mouse, the WIMP (Windows, Icons, Menus, Pointer) interface, and other characteristics could all have effects on Web-Based Learning. Table 3 lists some important differences between student-centered web sites and non-student centered web sites.

Table 3. Comparison between student and non-student centered science education web sites

Student-centered science education web sites	Non-student-centered science education web sites
Appropriate reading level	Adult reading level
Appropriate level of content	Adult content level
Content relates science content to subject matter of interest to students, e.g. sports, music, popular culture, fashion, etc.	Content presented in isolation in a more workman-like fashion, more abstract
Appeals to various learning styles, e.g. visual, aural, spatial, musical, kinesthetic	Does not necessarily appeal to various learning styles, efficient reception learning
Provides career information	Does not provide career information with the exception of posting job opportunities
Appeals to different sensory modalities, use of sound, animation, visual imagery, simulation of other senses in virtual worlds	Does not necessarily appeal to different sensory modalities
Has readily apparent educationally appropriate goals and objectives	No readily apparent educationally appropriate goals and objectives
Contains means of self-evaluation of progress	No means of self-evaluation
Encourages active exploration	Passive, does not encourage exploration
Ascertains students' present knowledge and builds on this	Ascertains site visitors' present knowledge and builds on this
Holistic, meets students' needs, academic, social, etc.	Meets academic needs primarily
Children's language and ideas are incorporated into the site	Children's language and ideas are not incorporated into the site

Obviously there are many other important differences that could be incorporated into Table 3. The most important principle to remember is that web site developers need to learn as much as possible about the students, their interests, abilities, prior experiences, and needs, and this information needs to be incorporated into the design of the web site.

Development of an Web Site Evaluation Instrument (WSEI)

A major goal of this project was to develop an instrument to analyze the processes and products of educational web site development. As a result of the analysis of data obtained from various sources during the Student Genome Project, the instrument seen in Table 4 was developed. This instrument is not intended to be used to rank web sites. Instead it should be used as a diagnostic tool to explore the characteristics of an already developed web site or as a resource when creating new web pages. The instrument can be used as a paper version or the data may be entered directly into an Excel spreadsheet. The form can be accessed in either html format or Excel format at the following URL: http://www.nyu.edu/education/scied/wbiform. The WSEI is in the form of a checklist. Each item is scored by adding or subtracting a point for each item as indicated on the score sheet. If an item can not be determined, a zero should be entered. Obviously many of the decisions of whether to add or subtract points were very arbitrary but in most cases, these were based on expert opinions or the authors' best judgements. In

Edward Tufte's (1997) book *Visual Explanations*, a principle entitled the "smallest effective difference" was described in which the amount and clarity of information conveyed in a visual display should always be maximized. Tufte felt that it was counterproductive to use many different colors of text arbitrarily. Instead, monochrome variations such as boldface should be fully utilized first before resorting to another color. A new color should be used for a reason and in a consistent manner, otherwise a profusion of colors, fonts, and text sizes could actually be quite confusing. An example of a controversial item would be the use of frames. Frames are now widely used on the World Wide Web and opinion is divided on their usefulness. Frames do have the advantage of allowing one part of the web page to remain in view while other links are visited. However, there are some problems, e.g. reducation of display space, visitors being trapped in a web site against their will, problems printing pages with frames, and also the lack of obvious indication of a page's URL while in a frame. The presence of frames on a web page therefore, leads to subtraction of a point for that page. However, if there is an alternative page without frames, a point will be added. The WSEI was used to evaluate samples of pages from the Student Genome Project web site http://www.cat.nyu.edu/sgp, and one other, the Math, Science, Technology, Enhancement Program (MSTEP) web site found at http://www.nyu.edu/projects/mstep/.

Table 4. A Web Page Evaluation Instrument (Developed by Murfin and Go, 1998)

Web Page Evaluation Instrument

CATEGORY		COMMENTS
Title of webpage		
URL		
Webmaster's email address		
Date last updated		
Size in bytes		
CATEGORY	POINTS	COMMENTS
COMPATIBILITY		
Platform independent (Mac and Wintel) +1		
Browser independent (Netscape and Internet Explorer) +1		
TOTAL COMPATIBILITY		
PEDAGOGY		
No science education objectives -1		
Science Education objective +1		
Educational objectives, non-science skills +1		
Improve attitudes towards science +1		
Appeal to special groups/types of students +1		
Appeal to many learning styles +1		
Appeal to predominantly one learning style +1		
Entertainment objectives +1		
No educational objectives -1		
TOTAL PEDAGOGY		
TARGET AUDIENCE		
Elementary school students +1		
Elementary school teachers -1		
Middle school students +1		
Middle school teachers -1		
High school students +1		
High school teachers -1		
Parents -1		
The general public -1		
Scientists -1		
TOTAL TARGET AUDIENCE		

CATEGORY	POINTS	COMMENTS
METHOD OF PRESENTATION		
Frames -1		
No Frames +1		
Text only -1		
Images only -1		
Text and images +1		
Need to scroll down page -1		
Use of bulleted or numbered lists +1		
Use of tables +1		
Other special devices, e.g. metaphors, stories, game format, etc. +1		
Arbitrary icons -1		
Meaningful icons +1		
TOTAL METHOD OF PRESENTATION		
TEXT CHARACTERISTICS		
> 4 different fonts used -1		
> 4 different variations in font size -1		
> 4 different font colors used		
Text clearly legible +1		
Text and background similar in color -1		
TEXT VARIATION SCORE		
INTERACTIVITY		
hyperlinks - text links used +1		
hyperlinks - links on images +1		
Imagemaps used +1		
hyperlinks within web site +1		
hyperlinks outside web site +1		
Animation +1		
Quicktime movies +1		
Other video formats +1		
Sound files +1		
Javascript +1		
Java applets +1		
ActiveX +1		
Shockwave movies +1		
VRML +1		
Quicktime VR +1		
Other +1		

CATEGORY	POINTS	COMMENTS
Use of forms +1		
Use of guestbooks +1		
Use of webboards +1		
Use of other cgi-scripts +1		
TOTAL INTERACTIVITY		
CONTENT		
Content areas included - Biology +1		
Content areas included - Chemistry +1		
Content areas included - Physics +1		
Content areas included - Earth Science +1		
Content errors - typographical errors +1		
Content errors - non-typographical errors +1		
Sources of content - not indicated -1		
Sources of content - from textbook +1		
Sources of science content - from scientist +1		
Sources of science content - web site developer -1		
Sources of science content - from other science web site +1		
Sources of science content - from individual, non-scientist -1		
Sources of science content - from students +1		
Sources of science content - science teachers +1		
TOTAL CONTENT		
WEB SITE DEVELOPER INFORMATION		
Area of expertise - Science +1		
Area of expertise - Science Education +1		
Area of expertise - Computer Science +1		
Area of expertise - Educational Technology/Instructional Design +1		
Area of expertise - Web site design +1		
Area of expertise - other +1		
Occupation - High school student +1		
Occupation - High school teacher +1		
Occupation - University student +1		
Occupation - University professor +1		
Occupation - Professional web site developer +1		
Occupation - Amateur web site developer +1		
Occupation - Other +1		

CATEGORY	POINTS	COMMENTS
TOTAL WEB SITE DEVELOPER INFORMATION		
Other developer information		
What are the educational objectives of your web site?		
Describe typical users of your site and the experience you expect them to obtain as a result of their visit?		
Who supplied content information for your site?		
Who determined the method of presentation of information of your site?		
SUMMARY TABLE OF RESULTS		
TOTAL COMPATIBILITY		
TOTAL PEDAGOGY		
TOTAL TARGET AUDIENCE		
TOTAL METHOD OF PRESENTATION		
TEXT VARIATION SCORE		
TOTAL INTERACTIVITY		
TOTAL CONTENT		
TOTAL WEB SITE DEVELOPER INFORMATION		
GRAND TOTAL		

A Theoretical Model for the Development of Web-Based, Student-Centered Science Education Resources

The final goal of this paper was to use the knowledge gained from the evaluation of an experiment in web-based instruction and learning, The Student Genome Project , to create a theoretical model for the development of web-based science learning experiences. The model is illustrated in Figures 1 and 2 and Table 5. Figure 1 displays an overview of the process of web site development from the beginning to end. Note that feedback from students and teachers is integral to the model. Students and teachers are also included as "Web Site Developers" in the model and the full team required is listed in Table 5. Finally, Figure 2 shows examples of possible web-based pedagogical approaches, and Table 6 gives specific examples of cognitive strategies used in the Student Genome Project.

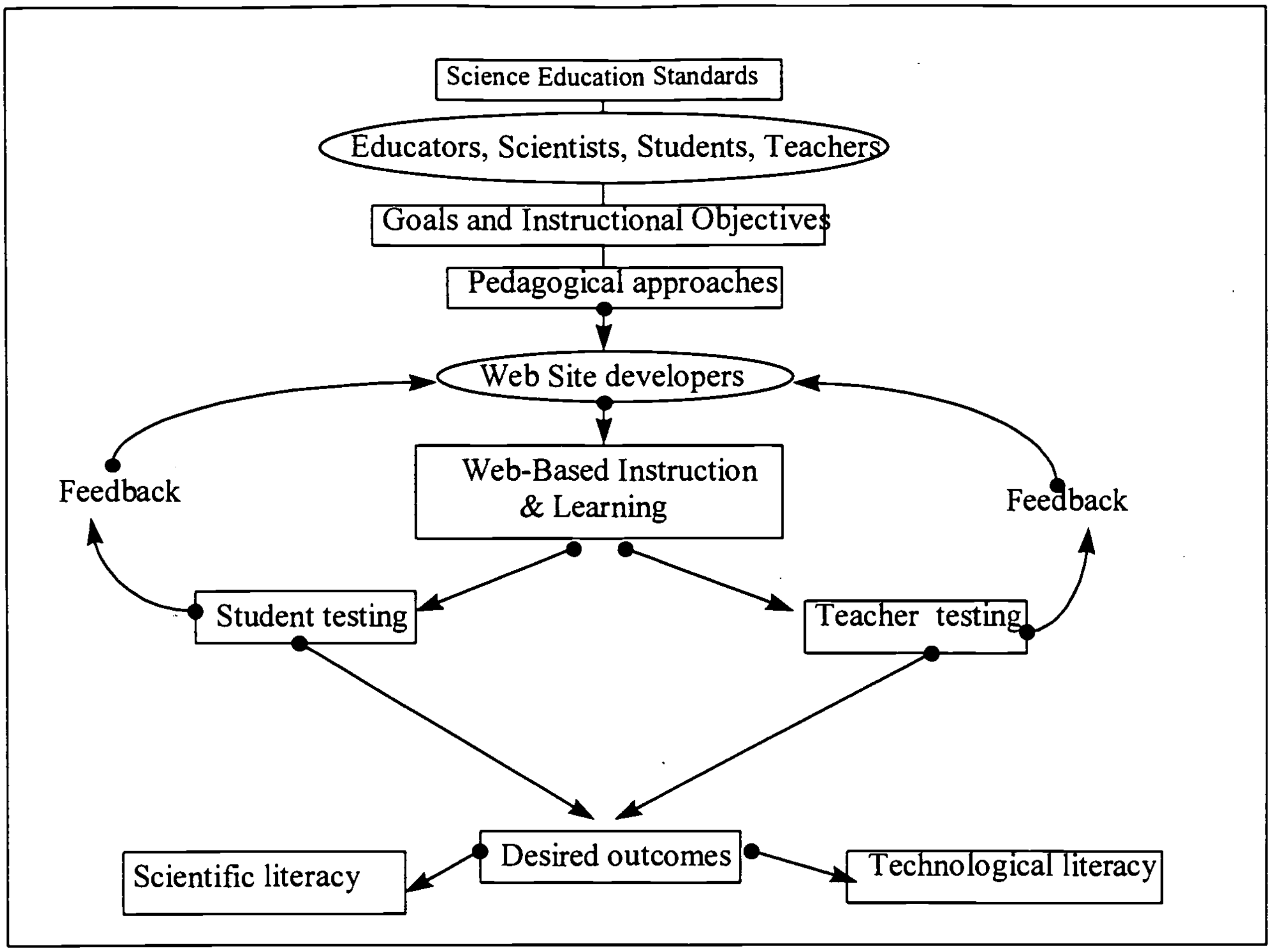

Figure 1. A theoretical model for the development of web-based, student-centered, science education resources.

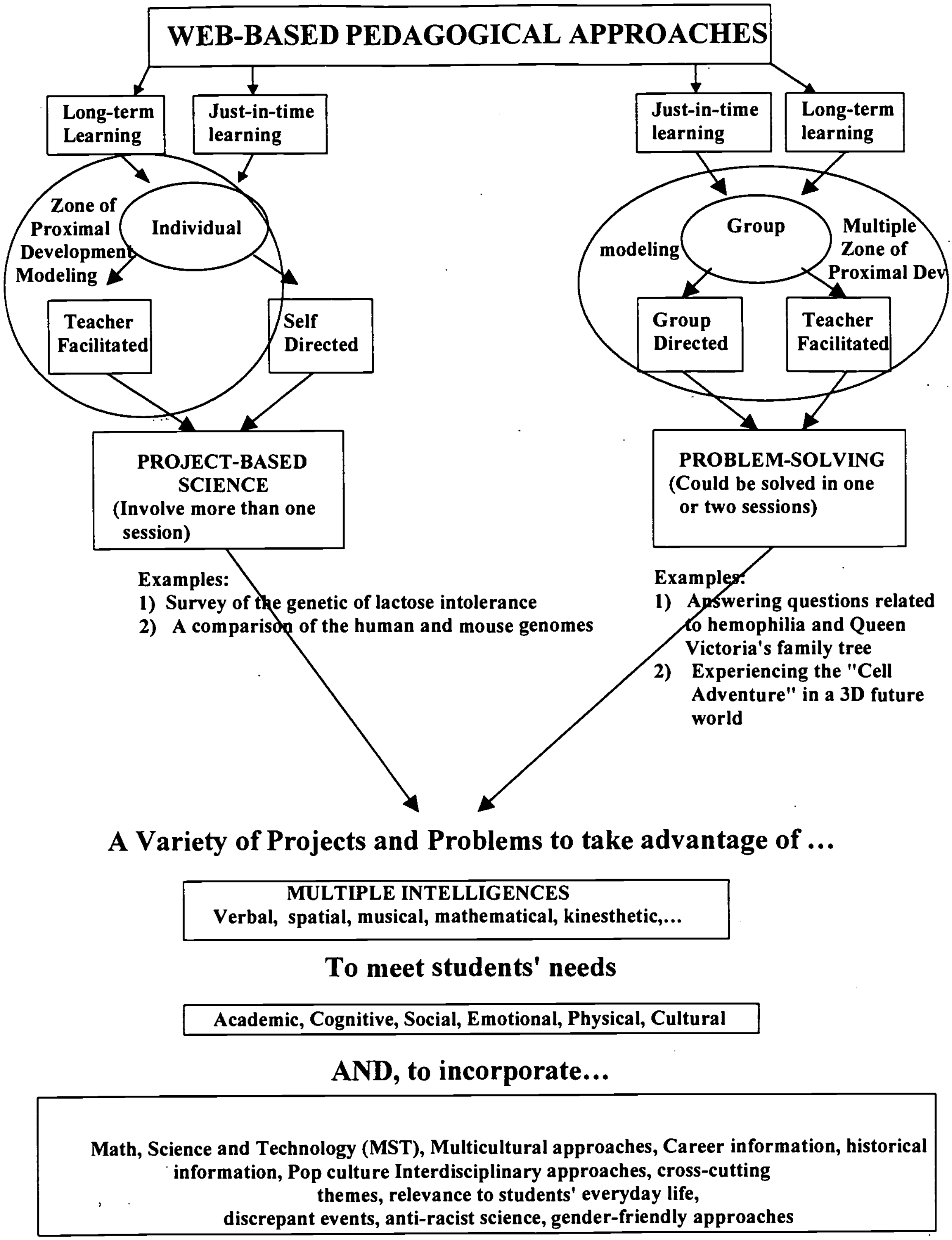

Figure 2. Web-based Pedagogical Approaches

Table 5. Web-Site Developers and Their Roles

Instructional designer	storyboarding, interface design
Computer programmer	coding, debugging, maintenance
Web designer	HTML, site maintenance
Graphic artist	images, icons, animation, Interactive Multimedia
Writer	storylines, grammar, spelling, scripts
Educator	monitor adherence to goals and objectives
Scientist	provide, validate and check science content
Students	idea generation, monitor development, ongoing testing

Table 6. Specific Examples of Cognitive Strategies in Web-Based Instruction

Problem	What is the Human Genome Project?	Should scientists be allowed to clone humans?	Should insurance companies be given access to genetic data?
Cognitive approach	Increasingly Complex Microworlds (ICM) framework	Case-based reasoning Shared cognition Cognitive apprenticeship	Situated cognition, shared cognition, case-based reasoning, cognitive apprenticeship
Sample activity	The SGP "Cell Adventure"	On-line cloning debate	Court room simulation
Expected outcome	Understand the purpose and consequences of HGP	Understand the benefits and dangers of human cloning	Ability to make an informed decision using scientific information

(Brown, Collins, Duguid, 1989; McLellan, 1996)

It is obvious that the development of most web sites does not follow the model proposed in this paper, and the creation of the Student Genome Project web site was no exception. There are serious financial and time constraints that impose severe limits on what can be developed on a web site. Other important barriers are the blinders imposed on most of us as a result of our training in specialized fields. To take full educational advantage of a novel new medium and to create useful new tools, we must break out of old ways of thinking, and this requires new ways of working together. Collaboration among the people involved in projects such as this, with respect for the perspectives and expertise of each is crucial if a coherent and integrated program of the enhancement of science education is to be achieved (NRC/NAS, 1996). The teacher, the scientist, the programmer, the artist, and most importantly, the students will need to work hand-in-hand if we are to develop genuinely authentic science learning experiences on the Web.

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