

Project Report

Team Halla

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Executive Summary

This project report summarizes the entire process Team Halla was involved in to develop instruction on cells and their parts. This report is composed of three main sections: analysis, design and development, and evaluation. In the analysis section, lesson objectives are first presented. The sub-sections of needs, learner, and content analysis present detailed information on the process used and major findings of each analysis. Following this, various contexts in which our instruction can be implemented are discussed. Our justification of choosing Reigeluth's approach, along with specific examples embodied in our instructional material completes the analysis section. The design and development section describes the setting of our instruction as well as the activities that make up the instruction. This section goes on to explain the project development process by use of a diagram. This section further explains our team's key development decisions for effective and easy instruction. It ends with expected maintenance and distribution requirements. The evaluation section of this report focuses on our team's assessment of the instruction achieved through expert review, design team review, and a usability test. This section discusses procedures employed, major findings of each evaluation procedure, and corresponding revisions we made in detail.

Analysis

Objectives for the instruction

The purpose of the instruction is to teach fifth and sixth graders the concepts of cells and their parts, using a supplemental tutorial. The overall goal for our instruction is to help fifth and sixth graders to understand the characteristics of cells, identify the main features of cell parts, and discriminate the similarities and differences between plant and animal cells. The specific objectives are as follows:

- Given graphic examples of living things and non-living things, all learners will be able to identify which examples are made up of cells.
- Given a graphic example of a small, young living thing and its mature, larger counterpart, all learners will be able to identify that the growth is caused by the reproduction of cells.
- Given the description of the functions of cell parts, all learners will be able to identify the cell parts matching the description.
- Given graphic examples of cell parts, all learners will be able to identify the cell parts by shape.
- Given graphic examples and descriptions of the functions of cell parts, all learners will be able to identify the cell parts by shape and function.
- Given a graphic example of a cell, all learners will be able to match the name of cell parts to their nickname.
- Given graphic examples of an animal and a plant cell, all learners will be able to discriminate which is an animal cell or a plant cell.
- Given graphic examples of animal and plant cells, all learners will be able to identify how the structures of each differ.

Process used for this analysis

The process used for needs, content, learner, and context analysis involved four steps: preliminary analysis, planning analysis, conducting analysis, and analyzing data. Detailed steps of each phase are as follows:

Preliminary analysis

Our team embodied an initial analysis plan through brainstorming sessions, team meetings, and preliminary research. In the first team meeting, we determined the proper topic for the instruction, considering possible resources given our current situation. We finally chose our topic, *cells and their parts*, because of the familiarity of content, the possibility of using graphic images, and the feasibility of a usability test. In order to conduct preliminary research, Ray checked out the Indiana Academic Standards for K-12 science education and Nari looked for some educational Web-sites about cells. Myonghee searched several science textbooks for elementary school students at the Education library of Indiana University (IU).

Planning Analysis

In a second meeting, we decided that the sections of the analysis be divided among team members in this way: Nari would take responsibility for searching for Web-sites, administering questionnaires to learners, and writing learner analysis report. Ray would be responsible for conducting interviews with learners and writing needs analysis reports. Myonghee would search for science textbooks and other science books, interview elementary school teachers, and write content analysis report. We wrote up our analysis plan reflecting such decisions and also developed a schedule and timeline for our analysis

After our primary instructor, Professor Boling, and the secondary instructor, Ugur, offered us feedback on our analysis plan, we modified lesson objectives. Ugur mentioned that some of our lesson objectives lacked the elements of degree and conditions (e.g. *learners will be able to explain what cells are in their own words*). Later, after Professor Boling compared our analysis plan with design plan, she pointed out that the target behaviors described in the objectives (e.g. *explain the basic structure of cells in their own words*) were not consistent with the nature of practice and test described in our design plan. Based on the advice, we made appropriate changes in our instructional objectives (e.g. *given graphic examples of living things and non living things, all learners will be able to identify which examples are made up of cells*).

Conducting Analysis

The needs analysis was conducted by reviewing Indiana Academic Standards for science education and by interviewing two elementary school teachers, Mrs. Lisa Stucky and Mrs. Elizabeth Broaddus. We also administered a questionnaire to twenty eight sixth graders and interviewed five sixth graders to gauge their current level of understanding of cells and their parts. We also conducted learner analysis through the questionnaires and interviews with the sixth graders. For convenient data gathering purposes, we used the same questionnaires and interviews for needs and learner analysis. We obtained information on general characteristics of our target learners, pre-knowledge of the topic, preferred learning styles, and computer skills. For content analysis, we searched science textbooks, other science books, and Web-sites, and contacted Mrs. Stucky again. Our developed content was reviewed and approved by SMEs for its accuracy and appropriateness. During the interviews with teachers and sixth graders, we also collected information for the context analysis.

Analyzing the Data

For the needs analysis, Ray and Myonghee summarized the result of the interviews with two elementary school teachers. For learner analysis, Nari analyzed questionnaire data and all of us summarized the data of the interviews with five six graders. Myonghee completed the content and context analysis.

Detailed information on the needs, content, learner, and context analysis are discussed in the following sections. In each analysis section, process used and major findings are provided.

Needs analysis

For the needs analysis, we assessed both the ideal level and the learners' current level of understanding of cells and their parts. The assessment of the ideal level

was achieved through the review of Indiana Academic Standards for science education and interviews with two elementary school teachers. For the assessment of the current level, we administered a questionnaire to a class of twenty eight sixth graders and interviewed five of them. In the process, we identified a gap between the two levels of understanding of the target concepts.

The Process of Needs Analysis

To assess the ideal level of the understanding of the concept, we reviewed Indiana Academic Standards for science education for grade 5 and 6. The standards for grade 5 say that in grade 5, students learn that organisms are composed of a single cell or a collection of cells varying in appearance (Appendix A1). The standards for grade 6 say that in grade 6, students use microscopes to observe cells and recognize cells as the building blocks of all life. Six graders are also expected to be able to distinguish the main differences between plant and animal cells (Appendix A2).

Then we interviewed two elementary school teachers, Mrs. Lisa Stucky and Mrs. Elizabeth Broaddus (Appendix A3). Mrs. Stucky is a fifth grade teacher of University Elementary School (UES) in Bloomington, and Mrs. Broaddus is a sixth grade teacher at the same school. The teachers said they referred to the academic standards for general guidelines on the instruction. From this interview, we confirmed that fifth graders and sixth graders were expected to understand critical characteristics of cells and their parts, such as functions, similarities, and differences of them, with varying focus according to their grades.

To assess the current level of student understanding, we interviewed the same teachers. Mrs. Stucky mentioned that in UES, fifth graders learned about basic concepts of cells and their parts, including the functions of all the cell parts. She added that students sometimes experienced difficulty in learning nine cell parts and their functions, which is quite demanding for fifth and sixth graders. Though they succeeded in learning, they tended to end up memorizing the facts without personalizing the information. She also mentioned that even if teachers and students wanted to have practices in a computer lab, time constraints did not allow for that. Mrs. Stucky finally pointed out that a supplemental material would be useful in assisting learners in understanding the concept more effectively and efficiently. Mrs. Broaddus was also excited about the development of a supplemental material on the topic.

In addition to the interviews, we distributed questionnaires to twenty eight sixth graders and had them complete a questionnaire. This survey took place in UES as well. In this survey, the students answered that they had learned about cells and their parts in their fifth grade. This questionnaire included three questions on cells and their parts (Appendix B1): 1) Can you explain what cells are? 2) Which one is a cell part? (arteries, mitochondria, veins, capillaries), 3) Can you describe what cell membrane does? In response to the questions, 55 percent, 50 percent, and 75 percent of the students respectively failed to give the correct answer. Regarding the question of "Was it easy to understand cells, when you were taught about them?", approximately 61 percent of the students answered no.

We then conducted follow-up interviews with three of the students. In the interviews, we asked the students to describe what they knew about cells and their parts (Appendix B2). The interviews confirmed our findings from the questionnaire that many of our target learners did not have a clear understanding of cells and their parts yet. One of the students provided information that at first it was hard to understand what cells are, because she had to assume that things

invisible to her actually exist and work. These interview data were also consistent with the preliminary interviews Myonghee had conducted with sixth graders. In both of the preliminary interviews, the sixth graders knew the term of “cell”, but admitted that they did not know what it was. Regarding the cell parts, they listed one to three parts, but none answered correctly regarding cell functions.

Including all of the interviews, three male and two female sixth graders were interviewed. Academic achievement levels varied from low to high. Three American and two international students were interviewed.

Needs identified

By referring to our research from the Indiana Academic Standards and the interviews with Mrs. Stucky and Mrs. Broaddus, we found out that fifth and sixth graders were required to understand major features of cells and their parts. Through the interviews with the teachers, we also discovered that many learners experienced difficulty in understanding these concepts. These findings were confirmed by the student survey and follow-up interviews with sixth graders. Many of the learners had not mastered the concept of cells, though they had been taught about it at school; two thirds of the students who completed the questionnaire answered that they had difficulty in understanding the concept of cells. Through the analysis process, we identified a gap between the ideal level and students' current level of understanding of the concepts. Thus, we determined that there was indeed a need for a supplemental material on the topic in order to bridge the gap. Our instruction targeted this gap. The teachers interviewed showed a very positive reaction toward the possibility of supplemental material on the topic with a computer component.

Content analysis

We conducted the content analysis in a series of steps. The steps included consulting four science textbooks and several Web sites, interviewing a subject matter expert (SME), analyzing and organizing the content, and revising the content according to the SMEs' feedback and usability test. In the process of content analysis, we repeatedly checked to make sure our content was accurate and complete.

The Process of the Content Analysis

First, we surveyed science textbooks, teacher guides, science books, and Web sites in the Education library of IU and in the Monroe County Public Library in order to obtain valid, accurate information. Through the research, we found out that the topic of cells and their parts were mostly dealt with in sixth grade science textbooks. Only a series of science textbooks titled *DiscoveryWorks* included the topic of plant cells in the fifth grade textbook

Then we again consulted the fifth grade teacher at UES, Mrs. Stucky, to obtain useful resources on our topic, such as supplemental materials, and to get information on the nature of the content to teach, points to highlight, and teaching strategies appropriate to the grade levels and the topic. Through the interview, we also discovered that teachers of UES used the science textbook of *DiscoveryWorks* to teach cells.

After the interview, we analyzed the content to teach, primarily based on fifth and sixth grade science textbooks of *DiscoveryWorks* and their teacher guides. In

order to develop accurate and valid content, we crosschecked *DiscoveryWorks* with three other science textbooks. General information presented in the textbooks was more or less identical, though levels of detail varied across the textbooks. Then we decided on three sub-topics and detailed content in consideration of the nature of the topic and findings of needs and learner analysis. Three sub-topics and detailed content are discussed in the following section of “Content of Cells and their Parts.”

Our SMEs reviewed a draft of our instructional material for content accuracy. Mrs. Stucky and Christy Johnson, Ph. D. student in science education at IU, served as the SMEs. The two SMEs approved the accuracy and completeness of our content with the exception of two points. One is related to the fact that even dead things contain cells, even if they are not easily recognizable. Thus, we removed the picture of a window made of wood, which used to be living. The other is that the second lesson section (What are cell parts and their functions?) should also include the information that cell wall and chloroplasts exist only in plant cells, which we included only in the third lesson section (Are plant and animal cells same or different?). Based on the two points mentioned by the SMEs, we made corresponding revisions of the content of our instructional materials.

Using our instructional material, we implemented a usability test. Three sixth graders of UES participated in the usability test. While the three students were studying with our instructional material, we wrote down their questions and confusions that arose, using an observation checklist. After they completed the material, we asked them to complete an evaluation questionnaire (Appendix C1) and interviewed one of them to gather in-depth information on our instructional material. The participants provided us with information on comprehensibility of the content and suggestions for revisions. For example, two of them were confused about when they should practice with a computer. According to their feedback, we further revised our content. Procedures, major findings, and corresponding feedback are all discussed in detail in the evaluation section.

After the revisions were made according to the results of usability test, Mrs. Stucky reviewed our instructional content again and finally confirmed its accuracy and validity.

The Content of Cells and Their Parts

The content analysis revealed that our instruction actually involved learning twelve different concepts: the cell, the nine cell parts, the plant cell, and the animal cell. These concepts could be grouped into three main sub-topics to teach: 1) What are cells?, 2) What are cell parts and their functions?, and 3) Are plant and animal cells the same or different? The detailed content follows:

What are cells?

- Cells are basic units of all living things, including human beings.
- Cells are not exactly same in their shape and structure, but remarkably similar.
- New cells are produced from existing cells.

What are cell parts and their functions?

- Cell wall: surround and protect the cell; make the cell stiff and strong; supporter and protector of the cell; exist only in plant cells
- Cell membrane: hold and protect the cell; control the movement of materials into and out of the cell; gate of the cell
- Cytoplasm: a watery, gel-like material in which cell parts move; area of movement
- Mitochondria: produce and supply most of the energy for the cell; powerhouse of the cell
- Chloroplasts: contain chlorophyll and capture the energy of sunlight and use it to make food; food producers; exist only in plant cells
- Vacuoles: store food, water, and chemicals; storage tanks
- Nucleus: regulate and control all cell activities, acting as the “brain” of the cell; control center
- Nuclear membrane: surround and protect the nucleus; control the movement of materials into and out of the nucleus; gate of the nucleus
- Chromosomes: direct cell activities; director of the cell

Are plant and animal cells same or different?

- Both plant cells and animal cells have 7 cell parts: cell membrane, cytoplasm, mitochondria, vacuoles, nucleus, nuclear membrane, and chromosomes.
- In addition to the 7 parts, plant cells have 2 more parts: cell wall and chloroplasts.

Each of the topics presents generalities containing critical characteristics of the concept and suitable examples, followed by practices and test. We organized and sequenced the content in a logical prerequisite scheme, which prescribes subordinate concepts necessary to understand another concept must be taught first.

Strength of the Content Analysis

Our content analysis was conducted in close relation to needs and learner analysis. Important findings of needs and learner analysis affected the directions and decisions of content analysis. For example, results of questionnaires revealed that approximately sixty percent of the sixth graders surveyed did not have a clear understanding of cells. Accordingly, we determined that our instruction start with basic concepts of cells. Our content also incorporated learner characteristics and preferred learning styles revealed through learner analysis. Decisions regarding starting points, breadth, and scope of our instructional contents were heavily influenced by the results of needs and learner analysis.

For content analysis, we depended on fifth and sixth grade science textbooks and their matching teacher guides as primary sources of information. We believed they contained the information that most adequately meets the requirements of the state academic standards. Later, Mrs. Stucky, who had taught the content to

fifth graders, reviewed our instructional content for its accuracy and completeness. Therefore, our content well reflects academic requirements in terms of amount and complexity of the content appropriate to target grade levels.

As described earlier, our content was structured around three sub-topics. And detailed content of each sub-topic was developed as a separate section containing generalities, examples, and practice, while remaining connected with the other two parts. This organization enables learners to skip around the content and visit any section according to their current level of understanding. Thus, our instructional content facilitates learner control, maximizing the potential of a supplemental material.

Weaknesses of the Content Analysis

Though we referred to several science textbooks, we primarily based our instructional content on science textbooks of *DiscoveryWorks*. The reason was that teachers and sixth graders of UES who served as an SME and a sample of our target learners respectively used the textbooks. Contacting teachers and sixth graders of other elementary schools who used other textbooks might have offered varied perspectives, enriching our instructional content.

Learner analysis

We conducted learner analysis through two forms of survey: questionnaire and interview. For convenient data gathering purposes, we used the same survey for both the needs and content analysis. By looking at the data, we were able to identify the current knowledge of our target learners, determine entry points of our instructional content, and establish appropriate instructional and motivational strategies for our instruction. Process and important findings of learner analysis are as follows.

The Process of Learner Analysis

We administered a questionnaire to sixth graders. With a permission of an elementary school teacher, Mrs. Elizabeth Broaddus, we distributed a questionnaire to a sixth grade class of twenty eight students. The questionnaire consisted of four parts: 1) general information (e.g. gender, level of interest in science), 2) current knowledge of cells and their parts, 3) computer skills, and 4) preferred learning styles (Appendix B1). Through this questionnaire of a fairly large number of students, we collected data about a wide range of learner characteristics, such as academic performance levels, gender, and computer technology skills (Appendix B3).

We also interviewed five sixth graders to gather more in-depth information on their current science knowledge, interest in science, comfort level of computer skills, study habits, and preferred teaching and learning strategies.

Important Findings of Learner Analysis

General information: Out of eighteen boys and ten girls, about 40 percent of respondents said they liked science, whereas 60 percent disliked it. And 61 percent of the students replied that they had difficulty in understanding the concept of cells and their parts, when they learned about cells.

Current knowledge of cells and their parts: As indicated in needs analysis section, we found out that though all the respondents learned about the topic in their fifth grade, an average of 60 percents of learners failed to provide correct answers to three questions regarding cells and their parts. Thus, we determined that our instruction should begin with explanation of basic concepts of cells as an entry point and extend into more complicated concepts of cell parts.

Computer skills: Survey revealed that a vast majority of learners (27 out of 28) possessed a computer at home with Internet access. They mentioned that they were regularly using a computer either at school or at home, especially for computer games or for homework. Respondents replied that they experienced no great trouble in using a computer.

Preferred learning styles: In response to the question on their preferred way of learning science, students provided varied preferences. The three most common answers are hands-on activities and projects, use of pictures and visual illustrations, and fun ways.

Context analysis

We envisioned the use of our instructional material in various contexts and designed it with an emphasis on flexibility of use.

First of all, our material can be used in conjunction with a classroom lesson as a supplemental tutorial. In this case, the teacher plays a significant role. The teacher will decide to use our material and determine on the exact way of using it. Most typically, the teacher will distribute our entire material to learners and require them to complete it as an assignment. It will be used by all students after a main presentation in a classroom. Some other options are conceivable. For example, the teacher will decide to use the paper-based small practices, the Web-based practice, and the test after a classroom presentation. Or the main comic strip presentation and practice materials can be used prior to a classroom presentation. In both optional cases, the teacher will decide to use the selected individual components in classroom or ask learners to complete them as an assignment.

Our instructional material can also be used in a completely different context, i.e., independently of the teacher. In this case, parents and learners themselves will decide to use our material. It can be used in a variety of ways, for example, as a refresher lesson for students in need of review or as an enrichment lesson for advanced learners.

We provided several suggestions on the use of our instructional material in different contexts.

Instructional approach and justification for the approach

When designing our analysis plan, we decided to follow Davie's approach to concept learning as presented in class. Later, we switched our instructional approach from Davies' to Reigeluth's. We agreed that Reigeluth's approach was more suitable, given the nature of the concept we were teaching, physical objects rather than abstract ideas. We also agreed that we had a better understanding of the Reigeluth approach, as well as easy access to the article on concept learning by Dr. Reigeluth in our class readings (Reigeluth, 1997).

Reigeluth's approach emphasizes four features as important tactics for teaching concepts: generality, examples, practice, and feedback. Following are major aspects of Reigeluth's approach. Generality is a definition of a concept containing its critical characteristics that class members of the concept have in common. Usually generalities are presented with examples simultaneously for the facilitation of concept acquisition. After being provided with generalities and examples, learners need ample practices followed by feedback to be able to apply their newly acquired knowledge of the concept to new situations.

We felt that these focuses were appropriate for our instruction, considering the nature of our topic concept. Though cells belong to a class of physical objects (e.g. dog, desk), as opposed to a class of abstract ideas (e.g. freedom), they are invisible to human beings with naked eyes. In this situation, prototype formation through the use of visual examples is needed to enable learners to realize cells exist and function in reality. We agreed that presenting critical characteristics, along with examples, would facilitate the acquisition of this concept. Particularly, acquiring the concepts of cell parts and their functions is very challenging to learners, because learners are confronted with a task of learning about nine cell parts, each of which is invisible and has a different function. Without an effective means of presenting information, like the combination of the generality and examples, learners may have great difficulty. In addition, many examples benefit learners in discrimination and generalization. Regarding practices, we reasoned that multiple practices with feedback would help learners to personalize the complicated concepts. We assumed that mere presentation of generalities and examples do not lead to the acquisition of the concepts. For the reasons, we decided to use Reigeluth's approach for our instruction.

Our instruction reflects Reigeluth's approach in many ways. Numerous appropriate examples reflecting all four features of generality, examples, practices, and feedback are found in our instructional material.

Generality

Our content analysis revealed that this instruction actually involved learning twelve different concepts: the cell, the nine cell parts, the plant cell, and the animal cell. Our material presents generalities for each of these concepts. The generalities include critical characteristics that help learners to distinguish the members of the concept from nonmembers. For example, in the section of "What are cells?", our material provides the generality of cells as "Cells are basic units of all living things including human beings." For the cell parts, generalities presented include critical characteristics of each cell part, which are mostly related to their functions or physical characteristics. For example, the cell wall is described as "surrounds and protects the cell." Generalities are simultaneously presented with their matching examples, which will be described in greater detail in the following section of "Examples."

In order to enrich the instruction of generalities, we used several attention-focusing tactics. For example, we highlighted all generalities presented in comic strips in blue text and the comic strip panel containing these points is outlined in blue as well. We used italicized letters for attention-focusing as well. Finally, the generalities are presented again in the section of "Things to Remember!" at the end of each topic section.

Examples

Examples accompany each concept generality. Due to the use of comic strips, we could present generalities and examples simultaneously for the entire lesson. Each example emphasizes the critical characteristics in the generalities. Because our concepts belong to a class of physical objects rather than abstract ideas, our examples presented are mostly visual illustrations of the concept. Relevant examples illustrating main points are presented in the section of “Things to Remember!” as well.

Examples of a concept containing critical characteristics are first provided to help learners form a prototype. And then divergent examples that are different from one another in their shape, color, and size are presented. Given that cells vary across living organisms in these characteristics, we provided examples of various types of cells.

We also used matched non-examples for each generality. For instance, we presented pictures of non-living things, such as a computer and a cup, to explain the generality that cells make up living things. For the section on cell parts, for a particular cell part, we used some of the other cell parts as matched non-examples.

Practices

Our instructional material provides learners with multiple practice opportunities through paper-based small practices and a Web-based main practice. Learners complete the paper-based small practices after each main topic section to reinforce material that has just been read. After completion of all topics, the main Web-based practice is provided to integrate the material and prepare students for the final test.

In the practices, the focus was on helping learners to distinguish the members of a concept from its non-members. Practice items are all new ones that learners didn't encounter before. In addition to practice items concerned with concept classification skills, we added other types of practice items, such as multiple choice questions and fill-in-the-blank questions. These varied types of practice allowed the learners to actively engage with the content before the main Web-based practice.

Feedback

For both paper-based practices and the main computer-based practice, feedback on learners' performance is provided. For paper-based practices, an answer key is provided after the practice; the main Web-based practice features immediate feedback after every answer to emphasize critical concept characteristics.

Design and Development

Description of the instruction

Setting

Our instruction is a tutorial composed of paper-based and Web-based materials. The tutorial is flexible in its use; it might be used as a supplemental or independent lesson in a classroom or home setting. In any case, the location for

our instruction will be equipped with a desk, a chair, and lighting for the study of the paper-based material as well as a personal computer with Internet access for the study of the Web-based material. On the desk, there will be a writing tool, such as a pencil, and an eraser which will be used for the small practices in the main lessons and the test at the end of the paper-based material.

For the Web-based material, the minimum hardware system requirements will be a personal computer with at least a 500 MHz processor and 64Mb RAM, a color monitor, a keyboard, a mouse, a modem, and a graphic card, as well as at least 56K Internet access speed. Also, the minimum software requirements will be an Internet browser (Microsoft Internet Explorer, Netscape Navigator, or America Online) at least version 5.0, and the Macromedia Flash plug-in at least version 6.0.

Activities and sequence

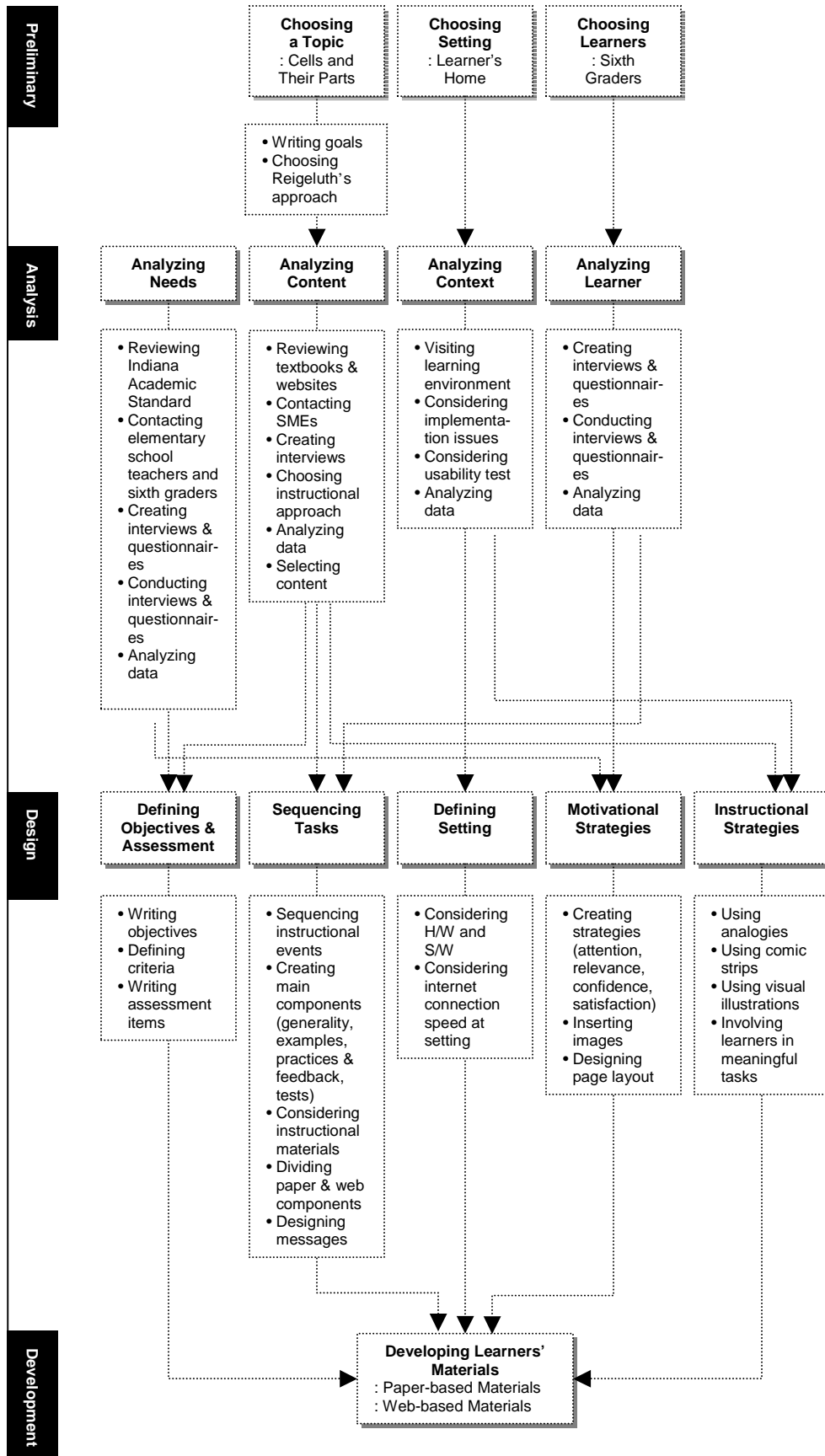
Our instruction consists of six activities in the paper-based and Web-based materials: introduction, comic strips, "Things to Remember," small practices, a main practice, and a test. The sequence of the instruction is as follows:

1. *Introduction (paper-based material)*: The instruction shows a picture of a microscope and asks our learners to recall their experiences of observing a cell with a microscope. Several questions are presented related to the topics of the instruction. Last, the three main goals are presented to our learners: to identify the main characteristics of cells, to identify the main features of cell parts and their functions, and to discriminate the similarities and differences between plant and animal cells.
2. *Comic strip (paper-based material)*: Based on the three goals, the comic strips consist of three lessons including 1) What are cells?, 2) What are cell parts and their functions?, and 3) Are plant and animal cells the same or different?. This section presents the content organized to achieve the objective of its lesson, using varied forms such as text, narrative, drawings and pictures. Each comic strip provides the generality and examples for each cell concept with the appropriate analogies related to the real world of our learners.
3. *Things to Remember (paper-based material)*: After each comic strip, this section summarizes the generality and examples provided in the comic strip with some key sentences and images in order to facilitate the transfer of new knowledge.
4. *Small practices (paper-based material)*: After each "Things to Remember" section, learners answer two or three easy questions about the generalities and examples for practice. Also, as feedback, the answer key presents the correct answers to the learners after all of the questions.
5. *Main practice (Web-based material)*: This section uses the Web to provide classification practice for each concept. The questions in the main practice are more difficult than the small practices in the paper-based material. At the end of each question, immediate feedback is automatically given on the learners' performance.

6. *Test (paper-based material)*: To assess achievement of the instructional objectives, this section provides ten yes-no questions. An answer key is provided with the teacher guide. Depending on the use of the tutorial, the teacher may provide the answer key to learners to check their own work, or may require the test to be submitted in class. If a parent or student is using the tutorial for independent study, they can likewise decide how to best use the answer key.

Development process supporting the instructional approach

In this section, we illustrate the process we used to design our instruction through the following diagram. The diagram shows major decisions we made, factors and processes that influenced those decisions, and the sequence of the decision-making. The decisions made are shown as boxes with drop shadows. The influencing factors and processes are shown as boxes without drop shadows. The sequence is indicated by dotted arrows. The major steps of the ADDIE model are indicated by black boxes. The outputs of one major step (e.g. preliminary, analysis, design, and development) serve as the inputs to the next major step.



Major components

The main components of our instruction are divided into experiential and tangible components.

Experiential components

The six main activities detailed in the “Activities and sequence” section are contained in four main experiential components: introduction, presentation, practice, and test.

Introduction

The purpose of the introduction is to gain the attention of learners, motivate them about the instruction, and to identify the three goals of the instruction: to identify the main characteristics of cells, to identify the main features of cell parts and their functions, and to discriminate the similarities and differences between plant and animal cells.

Presentation (generality and examples)

The intention of the presentation is to provide the criterial and functional definitions and the divergent examples about cells and their parts to learners. Also, the presentation is aimed at helping the learners to understand the content easily by maintaining their interest. Thus, this section presents the three lessons organized to achieve the three goals in the introduction, using comic strips as an instructional and motivational strategy. Through the comic strips, each of the three lessons provides generality and examples, using appropriate analogies and varied forms such as text, narrative, drawings, and pictures. At the end of each lesson, a “Things to Remember” section recalls the important definitions and examples to the learners as summary.

Practice

In the practice section, learners check out their level of understanding of the content, reinforce their knowledge, and correct their misunderstanding by answering questions and receiving the correct response and hints as feedback. Through this practice, they discriminate examples and non-examples and experience divergent practice about cells and their parts. The practice of our instruction consists of two types of practice: small practices in the paper-based material and a main practice in the Web-based material. The practice items reflect the three goals of the instruction and are also reflected in the test items. The practice items follow an easy-to-difficult sequence.

Test

Through the test, learners assess their final achievement in terms of the goals of our instruction. Depending on the use of the tutorial, the teacher may provide the answer key to learners for feedback, or may require the test to be submitted in class. If a parent or student is using the tutorial for independent study, they can likewise decide how to best use the answer key.

Tangible components

There are two types of tangible components for our instruction: learner instructional materials and teacher guide. The learner instructional materials consist of paper-based and Web-based materials.

Learner paper-based material

The introduction, presentation, small practice, and test component of our instruction are provided in paper-based form. This paper-based material begins with general information and guidelines about our instruction and provides presentation, small practices, and test in that order. Throughout the material, three comic strips, visual illustrations, and photographs with texts are used to arouse learners' interest and to facilitate their comprehension of the content.

Learner Web-based material

The Web-based material is used for the main practice component of our instruction. This material consists of 24 yes-no practice items, immediate feedback, and supplemental information. The number of correct and incorrect answers for each of the three main lessons is displayed to allow the learner to gauge their level of understanding. The material also visually displays when a learner has finished each lesson, as well as the entire practice. The material also features a Help function. The material is designed to be user-friendly and graphically appealing to sixth graders who are comfortable with using a computer. The material is also designed to be quickly downloaded at the 56K access speed of learners.

Teacher guide

The paper-based teacher guide provides instructors with lesson objectives and the key characteristics of our instruction. The guide also gives teachers detailed information about how to use the instruction in various contexts.

Key development decisions and justification

In this section, we will talk about the key development decisions for effective instruction and easy use.

Key development decisions for effective instruction

There are nine key development decisions to make our instruction effective for learners as instructional and motivational strategies as follows:

The use of paper-based materials for presentation and small practices

We chose to choose paper-based materials for these components because the use of paper materials allows learners to keep the materials for future reference and also to write on the materials for the small practices.

The use of Web-based materials for the main practice

We chose to use the Web for the main practice to allow the inclusion of a large number of practice items since practice is important in the learning of concepts. The use of the Web allowed us to add numerous practice items without adding many pages to our paper-based materials. The Web also allowed for the use of instant feedback, as well as easily facilitated repetition of the practice by the student.

The usage of comic strips for learners' motivation

Motivational strategies are especially important for learners to complete instruction, especially when the instruction is being used in a home setting or as an independent lesson. Through an interview with a sixth grader, we found out that many learners felt bored in learning about our topic, cells and their parts, at the fifth grade level because of the complex names of cell parts. Therefore, we determined to present the generality and examples about cells and their parts in the form of comic strips which we found that most sixth graders consider as their favorite media. We expect that the comic strips can gain and keep learner attention in order to complete our instruction without any stop in study. Also, we anticipate that the familiar stories and narrations of comic strips based on spoken English, not written English, will enable learners to understand the main concepts of the instruction more easily. The comic strips in lessons make learners more motivated to keep studying, and the increased motivation also can influence the high achievement of learners.

The usage of analogies for easy understanding

The name and main functions of each part of a cell still may be difficult for sixth graders to understand and remember even though we designed them in comic strips to facilitate learner understanding. Therefore, we determined to use appropriate analogies and nick names to explain the name and main functions for each part of a cell as a generality. Also, we used concrete examples related to the real world of sixth graders to provide familiar examples. For instance, in order to teach the function of a cell membrane, we explained that its function is to hold and protect the cell with the analogy of an entrance to pass to get into the shopping mall. We expect the analogies relevance to learners' life environments will motivate learners to study our instruction.

The usage of 'Things to Remember' section as summary

In order to assist learners in summarizing and recalling the generality and examples in comic strips, we inserted the section "Things to Remember" after each comic lesson. This section helps learners to re-organize the content of our instruction in a formal manner, similar to learner textbooks. The key words, images, charts, and diagrams in the section provide a big picture of the lesson, serving as a post-organizer to facilitate the transfer of new knowledge.

The separation of practices into small and main parts

For the practice section, we determined to use the Web-based material to provide more immediate and automatic feedback rather than the paper-based material. However, because of the limitation of short-term memory, learners might forget most content of the lessons if they would get only one change to practice -- at the

end of all lessons in the web-based environment. We decided that learners needed some simple practice between lessons and thus before accessing the Web-based material. Therefore, the practice in our instruction consists of two types of practice: easy small practices in the paper-based material and difficult main practices in the web-based material. We expect that the small practices will engage the learner with the content as he or she progresses through the lessons, and will increase learner confidence by successfully answering some easy questions. This will motivate them for the challenge of the main practice in the Web-based material.

The usage of two types of cell images: line drawings and photographs

To present generality and examples about cells with visualized resources, we decided to use two types of images: line drawings and photographs. As the first presentation in the lesson, we used line drawings to provide the proper detail level that learners need to focus on without including details they don't need. Also, the line drawings allow us to control color on the points of images we want to emphasize. Sixth graders might have difficulties understanding the main parts of a cell if only real photographs of cells are presented to them by complicating structures of a real cell. Therefore, only after showing the line drawings do we provide photographs as real representation of cells. The real photographs improve learners' abilities to discriminate real cells and their parts by noting critical and variable characteristics, thus applying their new knowledge to the real world.

The choice of color: orange, yellow, green, and blue

After researching the favorite colors of sixth graders through the textbooks, we chose four main colors for our instruction: orange, yellow, green, and blue. We expect these colors will motivate learners and satisfy boys and girls' sense of color equally during the study. We properly and consistently used colors to get and focus attention and to emphasize parts in complicated images and large amounts of text in comic strips. Also, we used the same color of cell parts in line drawing to that of the images of the analogies to help learners understand the relationships between two parts. To emphasize important content in comic lessons, we colored the outline of the boxes containing the key content in blue with blue text for the content inside of the boxes.

Key development decisions for ease of use

There are three key development decisions to make our instruction easy to use for learners and teachers:

The consistency of page design, shape, color, and font

To help users to search for information easily and fast, we maintained consistency in the page design, shape, color, and text font. We designed the page layout of our material considering proximity, alignment, and repetition to organize information in an effective way. To enable learners to imagine about cells, the topic of our instruction, we chose a circle and a round square as unifying themes to symbolize cells. We consistently used these themes in all pages of our material. Also we tried to keep the consistent tone of our four main colors when we emphasized the key information of images and text. For example, blue was used for important text and boxes, yellow for names of cell parts, and green for nick names of the cell parts in comic strips. For easy reading, we used only two

fonts in all material, Comic Sans MS for comic strips and Arial for the general information. The consistency of these elements in design also was kept in the Web-based material.

The use of Macromedia Flash as development and delivery tool for the main practice

The Flash tool allowed us to create all of the functionality we wanted to include in the practice material. In addition, we also used Flash based on the ubiquity of its plug-in player in most browser software. The platform independence of the tool also allowed us to develop the practice material while allowing users on many different types of computer systems to experience it without browser compatibility issues. This consequently results in less user technical problems.

The usage of three ring binders for the paper-based material

We decided to put the paper-based material for learners and instructors into three ring binders for easy use. The three ring binders allow users to easily add, remove or update pages compared to other formats such as a booklet or report.

Expected maintenance and distribution requirements

As our instruction involves two different mediums, we have two different sets of maintenance and distribution requirements. In this section, we will consider support for the continued use of our instructional materials in the future.

Paper-based Materials

For the paper-based material of our instruction, three-hole plastic folders are used to allow users to easily add, remove or update pages. We also designed our material to allow for copying of the small practices and test, with the assumption that teachers would be allowed to do this as part of a license agreement made with the purchase of the materials. Therefore, although the original materials were created in color, the color scheme will also allow for accurate black and white photocopying. To achieve this, text effects such as *bold* were employed for the emphasis of key words and important notes.

Our publishing company will be responsible for any necessary content or design revisions in each new printing of the materials.

Web-based Materials

The Macromedia Flash player is used for the main practice. The Flash development environment creates browser-independent and platform-independent Flash movies that play in the player; this will minimize learner technical issues.

The Flash Player is a standard player included in 99% of browsers. This will allow users on most computer systems to use the practice materials. A Flash movie can also be configured to check the browser for the latest version of the player. If a learner does not have the latest version, it can then be downloaded following on screen directions.

Should technical issues arise, our publishing company will provide email or phone assistance for learners.

Our publishing company will maintain the Web servers and store the content files necessary for learners to access the Web-based practice. The publishing company will also be responsible for content updates.

Evaluation

Methods used to evaluate the instruction

Formative evaluation of the instruction occurred during five expert reviews, several informal design team reviews, and a small group usability test.

Expert Review

For the expert reviews, subject matter experts (SMEs) were approached and asked their professional opinion in regards to a specific area of the instruction. Each of these experts was also asked to comment on the instructional strategies in general. The experts were shown the draft student materials at different stages in the development process. Their interview remarks were informally recorded on notebook paper.

Two SMEs reviewed content accuracy, proper sequencing, and prerequisite skills. One of these experts was Mrs. Stucky, a fifth grade teacher at the school of the learners that participated in the final usability test. The other expert was Christy Johnson, an advanced doctoral student in science education at Indiana University. Both experts had also been involved in the analysis phase of the project.

A professional graphic artist having more than ten years of experience also reviewed the materials. This expert reviewed visual and production quality issues such as layout, use of graphics, use of color, and use of fonts.

The final expert review was by a computer software developer with more than ten years of programming and interface design experience. The developer reviewed the web-based practice material for programming and usability issues.

Design Team Review

Concurrent with the expert reviews, the design team held several internal and informal design team reviews of the instruction. This involved one member of the team discussing the content from the perspective of students. The design team especially focused on usability and instruction length during these reviews.

Usability Test

The design team held a formal usability test on December 7, 2002. The usability test was conducted at the home of one of the design team members. The room had been arranged with computers for students to complete the computer-based practice (Appendix C2).

Since the material had been developed as primarily a self-study tutorial, there was not an instructor present at the usability test. Learners were told that the

materials had been designed to be used as self-study and that they should proceed as such.

Five sixth grade learners were invited to participate in the usability test. The learners were selected to represent different ethnicities, fluencies in English, and levels of academic achievement, based upon recommendations by Mrs. Broaddus, one of the sixth grade teachers that had participated in the analysis phase. On the day of the usability test, however, only three learners were able to participate. Of the three learners present, two learners were Koreans, and the other was Thai-American. The learners had been in the United States from 2-4 years and were fluent in English. The three learners present were above average in their academic achievement level.

In addition to a pre-test (Appendix C3) the instruction itself, and a posttest (Appendix C4), the usability test included an evaluation questionnaire (Appendix C1) that asked learners to rate their perceived understanding of the material, the usability of the material, and their satisfaction with the instruction.

The evaluation questionnaire also included open-ended questions asking the learners to comment on the strengths and weaknesses of the content, activities, materials, setting, and overall instruction.

Findings from evaluation

Expert Review Findings

Specific content accuracy issues and scope issues raised by Mrs. Stucky and Christy included settling on the number of cell structures to be taught (different text books taught from 7-11 different “essential” structures); and making the learning point clear that all living things have cells, but so do things that are made of something that used to be living (e.g. a wooden boat), although the cells are dead.

Mrs. Stucky also added that the first draft of the learner material did not include the additional plant cell parts, chloroplasts and a cell wall, in the second lesson on cell parts. Instead it was not mentioned until the third lesson about discriminating between animal and plant cells.

Christy also added that whatever the final decision on the depth of the material, there should be a focus on not misrepresenting anything, so that learners' future learning would not be impaired once they encountered high school and college science courses. Her own experience in teaching college level biology revealed that many learners have misconceptions about cells presumably learned in grade school that have to be unlearned before they can advance.

The graphic design expert reviewed the computer-based materials only. The graphic design expert concluded that several changes could be made. First, there was an inconsistent use of font types and sizes throughout the application for titles and text boxes. On some screens, Arial had been used; in other cases Times Romans had been used. The size varied from 12 point to 24 point. Further, the formatting of graphics was also inconsistent. In some cases, the same graphic had been used on separate screens but stretched on one or both to fit on the page. Not only was the resulting image inconsistent with other uses of the image, the graphic designer concluded that it was extremely aesthetically unpleasing.

Finally, the placement of titles was also inconsistent throughout the document. The placement ranged from one to three inches from the top of the screen.

The software developer likewise also concluded that several changes could be made to the computer-based materials. First, the interface design was not consistent throughout the application; buttons occurred in different places on different screens. Second, although the application allowed a user to track his location in a particular section, there was no functionality to let the learner know that she had completed a section. Finally, the programmer observed that the programming code was somewhat “buggy” and should be revised to be more effective and efficient.

Design Team Review Findings

The design team reviews attempted to determine the probable length of the instruction without a large degree of success. The overall instruction was scheduled to last about 60 minutes. Due to the familiarity of the material to the team members, design team members could work through the paper-based material very quickly. Likewise, the team members were able to move through the computer-based practice material and test very quickly.

One major usability issue was noted during the design team reviews. This was that the terminology and format of the main presentation material (the comic strips) did not always agree with the web-based practice material. This was due to the materials being developed at different times and by different individuals. Of interest is that this occurred even though both developers had been working from the same design specifications.

Usability Test Review Findings

Introduction

A significant aspect of the usability test was the manner in which it was conducted. For space considerations, all three learners were in the same room for the length of the usability test. In addition, two non-participants (friends of the learners) were present, in addition to the three observers. The large number of people seemed to distract at least one of the learners. The large number of people present and resulting distractions would most likely not be a feature of a real context (although it is possible depending on the study habits of learners and their living accommodations).

Observations and Learner Questions

The observers recorded anything that was unexpected during the usability test and compared notes later (Appendix C5). The observers likewise recorded any questions that were asked by learners during the usability testing. Table 1 describes these observations and questions.

Table 1. Observed learner behaviors and questions during usability test.

Section	Learner Behaviors and Questions
Introduction and Guidelines	Learner 3 is eating food and talking to others instead of working. "Kind and smart guy." (Laughs after reading this in the description of the comic book narrator.)
What are cells?	Learners laughing and smiling during exercise.
Cells and their Parts	Learners easily transitioned from first section to second section. Learner 3 is still hurrying. Learner 2 and 1 are still on section 1 and he is almost done with this section. He is turning pages quickly. He can't be reading that quickly.
Animal versus Plant Cells	Learner 2 is starting test without doing the computer practice!
Main Practice	"How do I go to the next screen?" (2) "Do I click Home now?" (after finishing first section) Learner 3 is not reading the feedback (unless he is a REALLY quick reader).
Test	"What is that?" (pointing to drawing of spider) Learner 3 seems to be hurrying now that Learner 1 is done. He keeps looking at Learner 1 and checking the progress of Learner 2.

Length of instruction

The observation instrument findings for the overall time in minutes of the instruction follow.

The usability test revealed that learners moved much more quickly through the instruction than was planned. This occurred in all sections of the instruction (Appendix C6). This suggests several possibilities: 1) the design team grossly underestimated the reading and comprehension abilities of sixth graders; 2) the sample of learners in the usability test, being above average, were able to proceed at a quicker pace than average sixth graders; or 3) the learners were moving unrealistically quickly through all parts of the instruction independent of their academic achievement level. Due to the small number of learners, the posttest scores and observations do not conclusively support one of these positions.

Assessment of Learning

The design team did not conduct formal validity or reliability tests on the pre-test or posttest. Given this, as well as the small number of questions on each instrument, and having only three learners, the instructional effectiveness of the instruction cannot be verified. It does appear, however, that some learning occurred, especially for two of the three learners, as displayed in Table 2. The learners scored 90% and 80% respectively on the posttest, after having both scored 50% on the pre-test.

Table 2. Estimation of learning that occurred due to instruction

Learner	Pre-test Percent Correct	Posttest Percent Correct
1	.50	.90
2	.50	.80
3	.50	.40

Learner 3 actually did slightly worse on the posttest than on the pre-test. As noted earlier, however, this was the learner who seemed to be distracted by all of the people in the room. This interpretation was based on the observations that the learner hurried through the instruction quite quickly, rarely read the practice feedback, and after the first learner had finished the instruction, quickly finished up despite having been only midway through the instruction.

Table 3 below compares the pre-test, practice and posttest performance. Discounting Learner 3, the presentation and examples section of the instruction seemed to improve the performance of the learners on the practice, and likewise that section and the practice served to improve the final performance on the posttest. The practice appears to have especially assisted Learner 1.

Table 3. Pre-test, practice and posttest performance – percent correct

Learner	Pre-test Percent Correct	Practice Percent Correct	Posttest Percent Correct
1	.50	.71	.90
2	.50	.79	.80
3	.50	.46	.40

Evaluation Questionnaire

The evaluation questionnaire was given to the learners at the end of the instruction. The questionnaire included several yes/no and open-ended

questions, as well as one Likert-scale question. The design team did not conduct formal validity or reliability tests on the instrument. The results are presented in Table 4.

Table 4. Learner evaluation questionnaire Likert scale results

Evaluation Statement	Results
Do you understand what this material is for? (Yes or No)	3 Yes, 0 No
Was it easy to understand the content? (Yes or No)	3 Yes, 0 No
Was it easy to do the practices with a computer (Yes or No)	3 Yes, 0 No
How much do you think you learned about cells and their parts through this material? (None, A Little, Much, Very Much)	2 Much, 1 A Little
How did you feel about learning through comic strips? (Open-ended)	<p>“It was fun.”</p> <p>“It was weird but OK I guess.”</p> <p>“Just normal.”</p>
Do you want to recommend that your friends use this material? (Yes or No)	2 Yes, 1 I don't know (written in)

These results indicate that overall the learners found the content and the instruction easily understandable and somewhat effective. The pre-test and posttest results confirm the latter response.

The satisfaction with comic strips as an instructional tactic seems to border on ambivalence based on the open-ended responses, despite several assurances from learners during the analysis phase that “I love comics.”

Finally, the results of the question on the use of the computer indicate that as the analysis suggested, the target audience enjoys using computers to learn.

Two other open-ended questions asked on the learner evaluation questionnaire asked learners to comment on strong and weak points of the instruction. The results are shown in Table 5.

Table 5. Learner evaluation questionnaire results on strong and weak points of instruction

Interview Question	Response
What do you think are good points of this instruction?	<p>“Things to Remember section helped me memorize the important things to know.”</p> <p>“The blue boxes in the comics blue showed me what was important to know.”</p>
What do you want to be changed in this material?	<p>“In the beginning, the picture of the organization of the material should be before the part with words since it is easier to understand.”</p> <p>“There should be some paper or something between the different parts.”</p> <p>“The test should be in color too.”</p> <p>“One test question said ‘This cell has seven parts. Is it an animal or plant cell?’ It could be both. The question should say ‘This cell has <i>only</i> seven parts.’ [emphasis added]</p>

Revisions to be made to the instruction

Frick and Boling (2002) recommend a formal process, based on the findings from the usability test, to determine the correct interpretation of the data and to decide upon prioritization for changes to be made to the instruction. They recommend prioritizing possible changes based upon importance to the final product and amount of work needed to make the revisions.

The design team followed a similar, though less formal, process in order to determine which revisions should be made (Appendix C7). After a review of the all of the collected data and an interpretation agreed upon by the design team members, a final list of possible revisions was compiled and prioritized.

Revisions Based on Expert Reviews

The major revision considered based on the expert review was the content issue of non-living things that came from living things having cells. A practice question on this had been added based on the expert reviews, but the information had not likewise been added to the presentation and example materials. The design team could either add this content to the presentation materials or delete it from the practice materials. Either solution would require a significant amount of re-work. The final decision was to do nothing. The design team concluded that the existing presentation materials did not mislead students, as the Ph.D. science education content expert had counseled against. Likewise, adding the information as practice extended the learner’s knowledge through the use of the

feedback while not penalizing the learner, which would have occurred had the same question been included on the final test.

A second revision based on Mrs. Stucky's feedback was to include the information that only plant cells contain the cell wall and chloroplasts in the second lesson regarding the cell parts.

A second revision to the material was to insure a consistent message design throughout the instruction. This was done based on the review of the graphic designer. Specifically, colors, fonts, graphics, language and layout were all made consistent throughout all sections: guidelines and introduction, presentation materials, practice, and test.

Revisions Based on Design Team Reviews

The major revision resulting from the design team review was that the materials were more formally divided into sections so that learners would be better cued as to where one section ended and one began and what they should be doing. This was done by inserting labeled lesson dividers. The Web-based practice was also modified to include instructions telling learners to take the paper-based test at the completion of the practice items.

Revisions Based on Usability Test

The highest priority based on the usability testing was to improve the navigation of the computer-based practice, as two learners had been confused during the usability test. The interface was re-designed to make the "next" and "back" buttons more apparent by including textual as well as graphic information.

A second level priority was a re-consideration of the instruction length as the usability test revealed that students were finishing the instruction much more quickly than the design team had estimated. After several discussions, it was decided that it was not critical that the instruction be completed in a certain amount of time, due to its self-study nature. (Another factor was that since the usability test learners were above average in level of academic achievement, this might have resulted in the shortened completion time.) The important point was to give teachers an estimation of how long a learner might take should the teacher want to assign the instruction as homework or even complete it in class. Thus, the decision was made not to add any additional material to the instruction to make it fill 60 minutes. Rather the teacher and learner materials were slightly edited to include an estimated range of 30 to 60 minutes for completion time.

Authorship of the report

Myonghee Kim authored the analysis section of the report. Nari Kim authored the design and development section. Ray Martinez authored the evaluation section. The team shared editorial and formatting responsibilities.

References

- Frick, T., & Boling, E. (2002). *Effective Web Instruction: Handbook for an inquiry-based process*. Unpublished manuscript.
- Reigeluth, C. M. (1997). *Module 1 application tasks (skills): Concept-using*. Unpublished manuscript.

Appendix A1:

Indiana Academic Standards for Grade 5

Appendix A2:

Indiana Academic Standards for Grade 6

Appendix A3:

Interview Questions with Elementary School Teachers

Appendix B1:

Questionnaire for Sixth Graders

Appendix B2: Interview Questions for Sixth Graders

Appendix B3: Questionnaire Analysis

Appendix C1:

Evaluation Stage: Usability testing evaluation questionnaire

Appendix C2:

Evaluation Stage: Usability testing still images

Two still images from the videotape of the usability test are included and labeled.



A learner prepares for the usability testing.



A learner reads the instructional material.

Appendix C3:

Evaluation Stage: Usability testing pre-test

Appendix C4:

Evaluation Stage: Usability testing posttest

Appendix C5:

Evaluation Stage: Usability testing observation instrument

Appendix C6:

Evaluation Stage: Usability testing instruction length data

Section	Designed Duration	Actual Usability Duration (Average)
Introduction and Guidelines	5	3
What are cells?	10	2
Cells and their Parts	15	5
Animal versus Plant Cells	10	2
Main Practice	15	5
Test	5	3
Total	60	20

Appendix C7:

Evaluation Stage: Learner evaluation questionnaire open-ended questions results on strong and weak points of instruction

	Possible Revision	Where Noted	Priority High = 1
1	Include instructions in section 3 telling learners to do the computer-based practice before the test, and then directing students from the computer-based practice to the test.	Usability Test	1
2	Improve computer-based practice navigation.	Usability Test	1
3	Revise the estimated time for the instruction or lengthen the instruction.	Usability Test	2
4	Sections need to be divided to let students know where they begin and end.	Design Team Review Usability Test	2
5	Presentation material images need to be revised to be more recognizable.	Usability Test	3
6	Font style and size need to be consistent in all instructional materials.	Expert Review	3
7	Titles and graphics need to be consistently placed in all instructional materials.	Design Team Review Expert Review	3
8	Re: cells for things made of once living things, either add content in presentation section or remove question from computer-based practice.	Expert Review Usability Test	4