The Research Base of Ignite! Learning Products

Wellesley R. Foshay, Ph.D.
The Foshay Group
www.foshay.org

January, 2006

Table of Contents

Rob Foshay, PhD, CPT
Rob Foshay is President of The Foshay Group. He is a recognized leader in the field instructional design, eLearning and competency-based assessment. He has more than 25 years of leadership experience applying instructional design research to plan truly cost-effective strategies and product architectures for eLearning, simulation and assessment.

His background includes a faculty position at the University of Illinois - Champaign, and experience as a high school social studies teacher and technology coordinator . His doctorate is in instructional design from Indiana University. He has written more than 70 major articles and book chapters on instructional design, technology and education/training, and speaks frequently before educators and trainers world-wide.

He is co-author of the award-winning textbook, Writing Training That Works: How to Teach Anyone to Do Anything, a practical guide for trainers based on current cognitive psychology and instructional design theory and research. He currently serves on the editorial boards of three research journals.

He has served on the Board of Directors of the International Society for Performance Improvement (ISPI) and the International Board of Standards for Training, Performance and Instruction (IBSTPI), as well as an ANSI/ASQ committee, which developed standards for training and education under the ISO 9000 system. He was cited by ISPI with Honorary Life Membership and a Distinguished Service Award, and is a Certified Performance Technologist. Dr. Foshay was also named a Fellow of the International Board of Standards for Training, Performance and Instruction (IBSTPI).

Executive Summary

Ignite! Learning has created a unique series of multimedia curriculum supplements in science and social studies designed specifically for the young teen student. With more than 2,300 Ignite! Instructional media products, teachers will find these resources to be modular, flexible, and easy to understand and use. Learners in their early teens (including upper elementary, middle school, and early high school) will find the learning activities a highly appealing and interactive learning challenge.

Research on brain-based (cognitive) learning supports many of the design features of the Ignite! software:

- Brain research confirms that young teens are particularly motivated by a high excitement factor and low effort factor (high confidence of success) — as is provided by Ignite! media.
- Research shows the values of today's young teen learners reflect those of the Millennial Generation. In comparison to their "Generation X" older siblings, today's learners are more positive, optimistic, team-oriented, and accepting of authority and rules, with a greater belief in progress and globalism. They have a fundamentally

different attitude towards learning, which has been conditioned by growing up with the Internet's instant access to information and communication. These messages are part of the subtext of Ignite! Learning's curricula.

- Ignite! media pieces are designed to create and reinforce cognitive structures (schemata), which research has shown are central to knowledge building. Facts and concepts are presented in a knowledge structure, using a combination of visual and verbal explanations. Research also has shown that learning in knowledge structures is critical to retention, deep understanding, and far transfer: all critical to the ability to apply learning to tasks beyond the context in which they were learned.
- Retention is strengthened by using informative master graphics that display knowledge structure and provide themes through many Ignite! media pieces. Research studies confirm the power of these graphics when used in close synchrony with audio to facilitate comprehension and minimize cognitive load.
- A feature of many Ignite! media pieces is original music, in idioms that appeal to students. This music increases retention of both the words and the structure of the lesson in a manner consistent with research on retention.
- In other Ignite! media pieces, stories are used to build retention consistent with research on experiential memory.
- Current research on motivation reveals three components: interest, confidence, and concentration. Ignite! media pieces are particularly well designed to build all three types of motivation in a manner that is designed to be effective with young teen students.
- The Reality, Inc. curriculum is based on current research on building a deep understanding of science. Some activities challenge students to predict or explain observed phenomena, the cornerstone activities of deep understanding. Other activities directly address misconceptions — an issue that current research has shown to be critical to understanding science.
- Research on technology adoption in schools has highlighted the need for technologies that are based on design assumptions that reflect the values and practices of the classroom. The sophistication of Ignite! Learning products lies specifically in their simplicity: their simple menu structure and self-contained delivery platform (the Curriculum On Wheels, or COW) constitute a system teachers can understand and integrate into their curriculum in minutes. This is one technology that teachers will actually use.
- Research on the total cost of ownership (TCO) of technology shows that indirect costs of support and implementation far exceed the direct costs of purchase. By contrast, the self-contained, reliable Ignite! Learning COW places no load on the technical support or network resources of the school.

Part 1

The Need

This is no time for status quo in education. Educators must deal both with the increased demands of the standards and accountability movement and significant changes in the profile of the students they teach. Many of the conventional approaches to curriculum and teaching need to be strengthened to obtain better results. Teachers are responding effectively to these challenges, but there is a great deal more to be done. In Part 1, we will examine the unique characteristics of today's young teen students. Then, we will briefly summarize the good news about recent advancements in achievement levels of middle school science and social studies – and the work that remains.

The Students

Young teens (including learners in upper elementary, middle school, and lower high school grades) are special people. Successful teachers, administrators, and parents of these learners understand this intuitively. Current research on brain development provides a scientific basis for this observation: the structure of the early adolescent's brain is quite literally in transition from a child's to an adult's (Casey, Tottenham, et al.; Giedd, Blumenthal et al.; Proverbio and Zani; Spear).

Particularly significant for learning is the discovery that this is the time when the brain literally "prunes" its many associations and builds the myelin sheathing around nerves to improve efficiency. Exactly what pruning and myelination takes place depends in large part on a "use it or lose it" principle: the cognitive structures that are being used, and the way in which they are used, have a great deal of influence on how the brain structures itself for adult life. Furthermore, the combination of hormone and brain structure changes in young teens has a great deal of impact on motivation: unlike adults, these students are prone to behaviors that have a high excitement factor and a low effort factor — goal-directed motivation which dominates adult behavior is much weaker in young teens. The conclusion: the best ways to reach these learners are different from the best ways to teach younger and older students. What, and how, students learn in these years has an effect on brain structure that will last throughout adulthood.

It's also important to understand how today's young teens differ from those of even a decade or two ago. Today's young teens are in the second wave of the Millennial generation (Howe and Strauss 2000; Howe, Strauss, et al. 2003), those children born after 1982 (the high school class of 2000).

Howe and Strauss synthesize demographic, social, and market research to make the case that today's students are more positive, optimistic, team-oriented, accepting of authority and rules, and have a greater belief in progress and globalism than their older "Generation X" siblings. They are smarter, with a fundamentally different attitude to learning that has been conditioned by the Internet's connectedness and instant access to global information, the video game culture (with its influences on brain development), and a strengthening consensus that being smart is "cool."

For the first time since television's widespread diffusion in the middle of the 20th Century, the Millenials are watching less TV than their older siblings. Instead, they are spending more time on other technologies useful for entertainment and schoolwork. The values, vision, and work style of the Millenials are different from previous generations, and reaching them in the classroom requires challenging a great many traditional assumptions and practices of conventional schooling (Education 2004). For example, we can conclude that these are students who need compelling and memorable knowledge “hooks” to draw them in; once engaged, they will use these “hooks” to guide instantaneous retrieval of full information when it is needed. By contrast, conventional textbooks seem needlessly restrictive, linear, incomplete, and out of date.

The State of Learning in Science and Social Studies

The sad fact is that in the United States, young teen students lag behind their Asian counterparts in science understanding according to the 2003 *Trends in International Mathematics and Science Study* (TIMSS) (Gonzales, Guzman, et al. 2004). Table 1 summarizes findings for 8^{th} grade, the center of the young teen years.

While this is a significant improvement over the previous 1995 study (in which U.S. students lagged behind some European countries and Australia), it still shows a gap in the international competitiveness of American middle school students. It is particularly important to note that reflective of current curriculum standards, the TIMSS test gives weight to scientific thinking processes as well as to science knowledge. Teachers need a variety of new tools and techniques to adequately meet both requirements: the traditional combination of textbook, conventional lecture, and “cookbook experiment” is not up to the task.

Country	**Score**
Singapore	578
Republic of Korea	558
Hong Kong	556
Japan	552
Hungary	543
Netherlands	536
United States	**527**
Australia	527
Sweden	524
Slovenia	520
New Zealand	520
Lithuania	519
Slovak Republic	517
Belgium (Flemish)	516
Russian Federation	514
Latvia	513
Scotland	512
Norway	494
Bulgaria	479
Romania	470
Iran	453
Cyprus	441

Table 1: National Average Scores, 8^{th} Grade Science
from the 2003 *Trends in International Mathematics and Science Study (TIMSS)*
(Gonzales, Guzman et al. 2004).

The results from the *National Assessment of Educational Progress* (NAEP) also show a positive trend, but still at a disappointingly low level of proficiency. Results are summarized in Table 2. Compared to 1996, there was a 3% increase in proficient students, and a 1% increase in advanced students. However, in 2000 just 32% of students were judged to be Proficient or Advanced.

Proficiency Level	% Science
Below Basic	39
At Basic	29
At Proficient	28
Advanced	4

Table 2: NAEP 2000, 8th Grade Science Proficiency Levels.[1]

With the current emphasis on standards and accountability, social studies has received considerably less attention than the other core subjects of the curriculum. Nonetheless, the most recent NAEP data shows clear signs of improvement over previous years — but with proficiency levels that are still disappointing. Results are summarized in Table 3. In Civics, just 23% scored at or above Proficient; in U.S. History, only 17% did as well; in Geography, just 30% were Proficient or better.

Proficiency Level	% Civics	% U.S.History[2]	% Geography
Below Basic	30	36	26
At Basic	48	49	44
At Proficient	21	15	26
Advanced	2	2	4

Table 3: NAEP 8th Grade Social Studies Proficiency Levels.[3]

These results are consistent with those of a 2002 global survey of young adults sponsored by the National Geographic Society (RoperASW 2002). For example, in the survey of Americans:

- Nearly 30% could not find the Pacific Ocean
- 56% were unable to locate India
- 81% could not name four countries that officially acknowledge having nuclear weapons.

While the study did not include middle school students, it does demonstrate the demand for improved geography teaching in schools at every level.

The good news from these data is that middle school achievement levels in science and social studies are showing positive trends, reflective of the hard work in recent years of teachers and administrators to raise performance levels. But clearly, we have a long way to go; achievement levels are still very low relative to our own expectations and the performance levels of many of our international competitors. Teachers must continue the search for innovative, new instructional strategies and curricula to improve on the results obtained by conventional textbooks and methods. In particular, they need teaching strategies and curricula closely attuned to the characteristics of young teens in the

1 Downloaded 1/23/2006 from http://nces.ed.gov/nationsreportcard/nde/viewresults.asp.
2 2001 NAEP test with accommodations.
3 Downloaded 1/23/2006 from http://nces.ed.gov/nationsreportcard/nde/viewresults.asp.
Numbers do not sum to 100% because of rounding. Geography and U.S. History is from NAEP 2001; Civics is from NAEP 1998.

Millennial generation. And, the curricula must be based soundly on the best research available.

In Part 2, we will examine the key instructional design features of Ignite! curricula. Then we will show how these design features were carefully based on current research on instruction.

Part 2

Key Instructional Design Features of Ignite! Learning Curricula

In Part 2, we will provide an overview of the key instructional features of the major Ignite! Learning curriculum materials in science and social studies. Because of its uniqueness, the science problem-solving series, *Reality, Inc.*, will be discussed separately in Part 4.

Instructional Model: Overview of Learning Activities

The Ignite! Learning curricula are organized in a hierarchical structure that includes:

Courses → Units → Topics → Learning Activities, including Media Pieces.

The instructional model is chunked as 10-15 minute learning activities, which are normally integrated into the curriculum 2 to 3 times per week, for a total of at least 30 minutes per week, or one period.

The 5 key activities include:

1. Begin each unit with a *Unit Challenge* worksheet. This worksheet provides a focus on the main themes of the unit. An example three-page worksheet from the unit introducing the scientific method is shown in Figures 1, 2, below. Each unit challenge includes instructions for a model lesson plan for the teacher and 1-3 worksheet pages for use by students (Figs. 1 & 2). Activities in the worksheets typically include:

    a. *Getting Started:* An activity that orients the students toward the main learning objective and stimulates recall of relevant prior knowledge.

    b. *Taking Notes:* An activity to stimulate active note taking while watching the media pieces. The activity consists of a prompt and blank note-taking space or a table or figure to scaffold note taking.

c. *Response*: Typically a small-group activity to review the content covered in the unit and help students formulate their response to the unit challenge. This is typically scaffolded with a worksheet that has a prompt, accompanied by blank space, a table, or a figure.

Name: ______________________

Scientific Method | General Science

Unit Challenge

Purpose: The Unit Challenges help students explore the big-picture issues and themes that tie together each unit of Ignite! content. These activities are designed to complement the Ignite! Topic Lessons.

Each Challenge presents students with a thought-provoking question. Working in small groups, students prepare a short response, in either written or oral form, in which they use knowledge gained by studying the unit's multimedia movies to formulate and defend a particular position. These responses can be used to stimulate further class discussion and exploration of the issues.

NOTE: In order to use this activity with your class for a particular Ignite! unit, you should plan on having students study the Ignite! movies from most of the topics in that unit. Otherwise, students will not have enough information to complete the Challenge activity.

Class time required:
15 minutes at the start of unit to organize students into groups and review the Challenge, and for the groups to discuss and record their initial thoughts and current knowledge of the issues.
20 minutes at the end of the unit for student groups to complete their responses to the Challenge.
Optional: 20-30 minutes for student groups to present their responses to the class.

Teacher Instructions:

At the Start of the Unit: Before studying any of the unit's topics or movies,

1. divide your class into teams of 3-4 students;
2. reproduce and distribute the unit's Challenge Worksheet to students;
3. decide whether teams will give oral presentations and/or written statements in response to their Challenge;
4. read the Challenge out loud and make sure that all terms and concepts are understood;
5. ask groups to complete Part One of their worksheets (Getting Started): They should discuss and write down their thoughts, based on their current knowledge, for how they might respond to the selected Challenge.

While the Class Studies the Unit's Topics: Over the next few days or weeks, as you are using the Ignite! Topic Lessons for this unit, occasionally remind students to record on their worksheets any information they have found in the Ignite! movies that might help them to develop or support their response to the Challenge. They should record this information in Part Two of their worksheets (Taking Notes).

After Completing the Last Topic of the Unit: Give your students 20 minutes to discuss and write up their responses to the Challenge. They can use the space provided in Part Three of their worksheets (Preparing Your Response). You might consider allowing them to review some of the movies from the unit. Then, have students give brief presentations of their responses (2-3 minutes each) and/or submit their written responses.

Figure 1: Teacher instructions for the Unit Challenge on the scientific method.

Name: ____________________ Scientific Method | General Science

Scientific Method

Careers in Physical Science

Background: How do scientists make discoveries? They use the scientific method. Making careful observations and measurements, analyzing data, and drawing conclusions are all part of the method. But even though it does not sound very scientific, a special kind of guessing is also a part of the process.

Challenge: Describe the scientific method, and explain how guessing is part of the process.

Tips:

- Describe the steps of the scientific method.
- Explain where guessing fits in.
- What makes something a *good* guess? Is any guess ok?

PART ONE – Getting Started

Directions: Based on what you already know, talk with the other members of your group about how you might respond to this challenge. Write your thoughts in the box below. You can change your mind later, after you have reviewed the Ignite! movies in this unit.

Notes:

Name: ____________________ Scientific Method | General Science

PART TWO – Taking Notes

Directions: As you view and discuss the Ignite! movies in this unit, be on the lookout for information that will help you develop a response to your challenge. Record that information in the box below. Use additional paper if necessary.

Notes:

PART THREE – Preparing Your Response

Directions: Depending on your teacher's instructions, work with your group to create a written or oral response to your challenge. Decide on what you want to communicate, and be sure to support your statements with evidence from the Ignite! movies. Use the space below for your response. Use additional paper if necessary.

Figure 2: Unit Challenge for The Scientific Method.

2. Work through each *Ignite! Topic,* which consists of 2 or 3 media pieces, accompanied by a C*lass Activity.* Ignite! media pieces include animations and self-paced interactive pieces such as timelines, maps, and cause-and-effect motion graphics. The self-paced media pieces typically include summary information, detailed elaborations, visualizations, and interactions. These media pieces serve as a resource to teachers who lead large- or small-group discussions, as well as to students working individually and in small groups. An example interactive self-paced media piece from the introductory unit on the scientific method is in Figure 3. A discussion of the design practices used in the main types of Ignite! media is below.

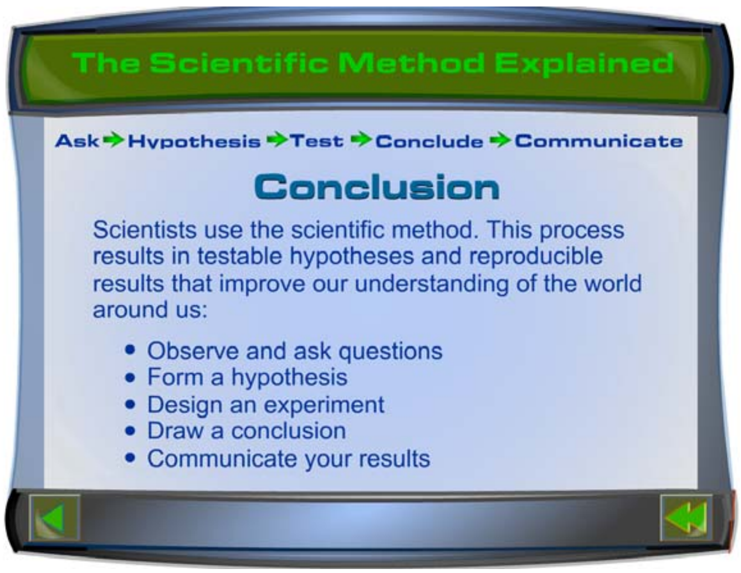
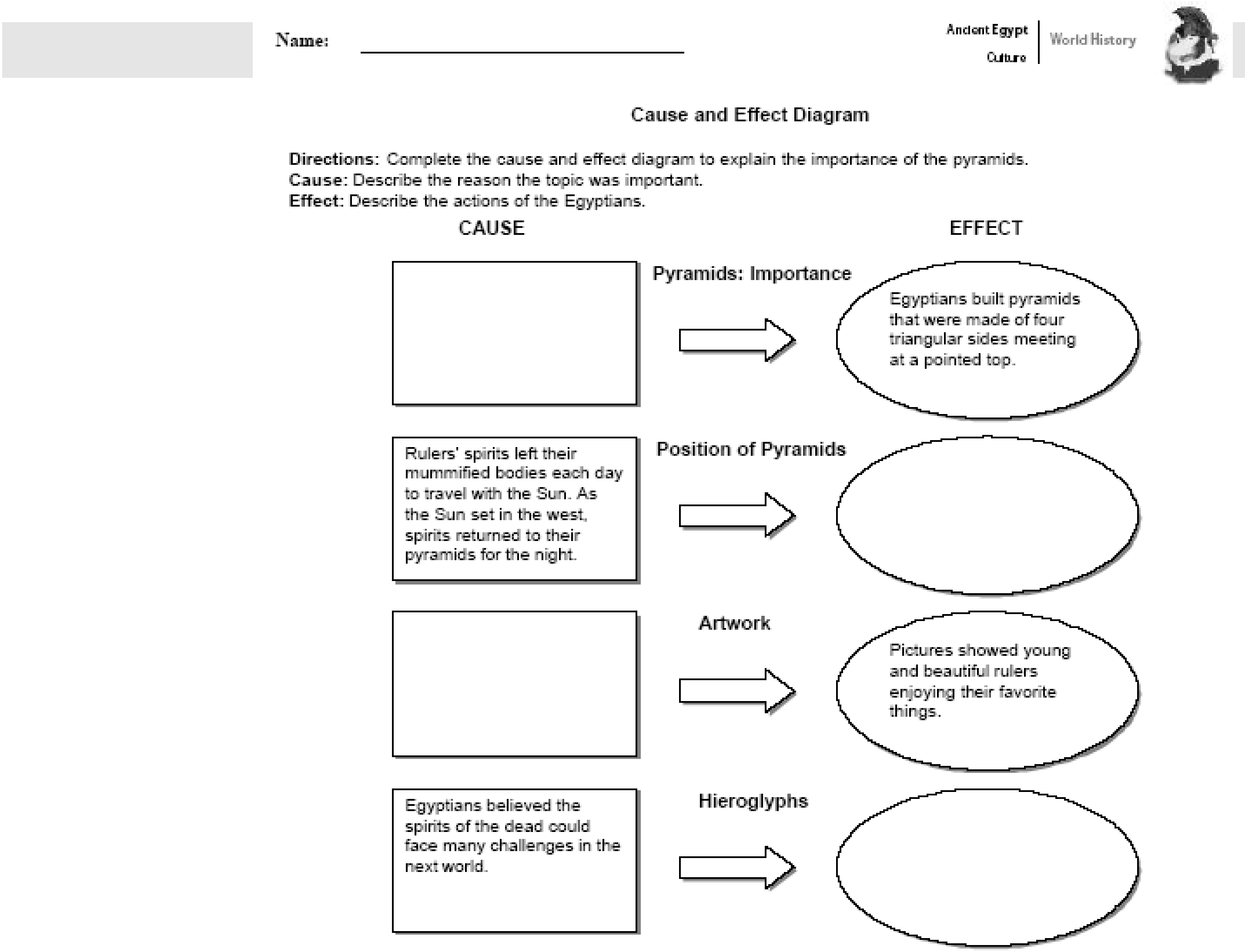


Figure 3: Media pieces such as slides summarize the main points and show relationships.

3. A suggested plan for using the Ignite! media pieces is in a *Topic Lesson.* This is a plan of student activities designed to help students understand and remember the key points of each media piece. An example from the Social Studies World History curriculum, an introductory topic on the ancient Egyptian pyramids, is shown in Figure 4.



Name: ______________________

Ancient Egypt | Culture | World History

Cause and Effect Diagram

Directions: Complete the cause and effect diagram to explain the importance of the pyramids.
Cause: Describe the reason the topic was important.
Effect: Describe the actions of the Egyptians.

CAUSE		EFFECT
	Pyramids: Importance →	Egyptians built pyramids that were made of four triangular sides meeting at a pointed top.
Rulers' spirits left their mummified bodies each day to travel with the Sun. As the Sun set in the west, spirits returned to their pyramids for the night.	**Position of Pyramids** →	
	Artwork →	Pictures showed young and beautiful rulers enjoying their favorite things.
Egyptians believed the spirits of the dead could face many challenges in the next world.	**Hieroglyphs** →	

Figure 4: Accompanying worksheet reinforces the understanding of why pyramids were built the way they were.

4. At the end of a unit, administer the *Unit Test* to individual students or the whole class. The test consists of about 30 multiple-choice questions.

5. Use records are recorded on the *Ignite! Success Chart*, which the teacher can use to track the effective use of Ignite! curricula.

The system also includes a glossary in a format similar to one in a textbook, and an index to allow direct access of any media piece in a curriculum.

Animations

The centerpiece of the Ignite! Learning experience is the Ignite! multimedia content: the library of more than 2,300 media pieces aligned to the middle school science and the social studies curriculum standards. Each topic typically includes 2-3 Ignite! media pieces. Among the types of media pieces are animations, each of which is 30 seconds to 3 minutes long. These can be quickly accessed though a hierarchical menu system (curricula also include a keyword index feature for direct access to any media piece). The user interface includes familiar buttons to allow the user to start/stop or skip forward or backward.

Animation Quality and Style

The animation is done with high production values comparable to TV cartoons, which appeal to young teens. The overall style is lightly humorous, but done in a way that does not obstruct the main message of the video. Characters often have humorous names, and they provide narrative continuity both within videos and across videos, as well as signaling the type of learning activity in the media piece. For example, a movie theater is the setting for encounters with The Detective, who provides examples to illustrate main points of the unit by investigating a mystery (Fig. 5).

Figure 5: The Detective repeats the definitions of each step in the scientific process, and describes how each step helps him discover why the milk in his boss' coffee has gone bad.

In a second example, Mortimer Gravitas, CEO of Reality, Inc,, provides an introduction to each unit in the Science curriculum by explaining the importance of science concepts in everyday life, and by providing an overview. An example is in Figure 6.

Figure 6: Mortimer Gravitas introduces the concept of the scientific method.

Music

A frequent feature of Ignite! animations is the use of original music, with lyrics that tell a story or present the content of the topic. The styles of music used, such as rock, hip-hop, and country/western, are popular and appealing to young teens. For example, the song used in Figure 7 tells the story of how the steps in the scientific method are applied to determine the effect of two different feeds (clover vs. hay) on weight gain in calves.

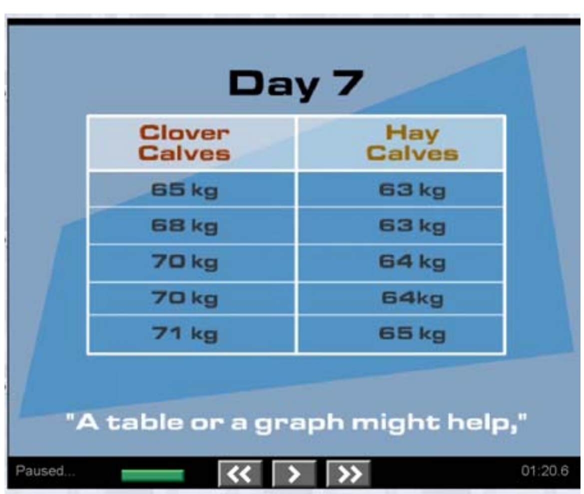


Figure 7: A catchy song describes the steps in a scientific experiment to determine if calves gain weight faster if fed clover or hay.

Visualization

Graphics are often used to express the relationship between concepts, and thus to convey the structure of content. In Figure 8, a visual analogy linking driving on a road to moving along a time line conveys the chronology of important moments in ancient Egyptian history.

Figure 8: Using the visual analogy of a road to a time line, the student "drives" past billboards with important moments in ancient Egyptian history.

Motion is often important to conveying concepts and relationships, and it is used in media pieces for this purpose. For example, Figure 8 is a scene from an animation that shows the relationship of planetary motion and orientation to the seasons.

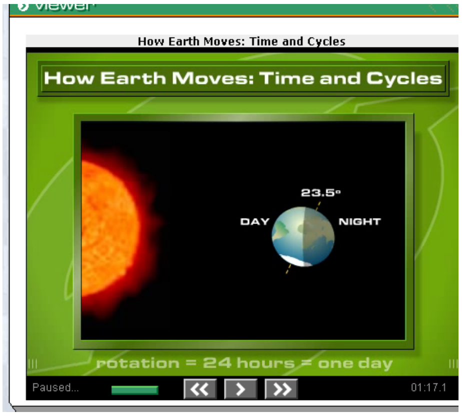


Figure 9: An animation shows the relationship of the earth's rotation to time and seasonal cycles.

Motion can be particularly powerful when used to show the behavior of living organisms and mechanical systems. The example in Figure 10 shows how this strategy is used to show the cytoskeleton of swimming cells.

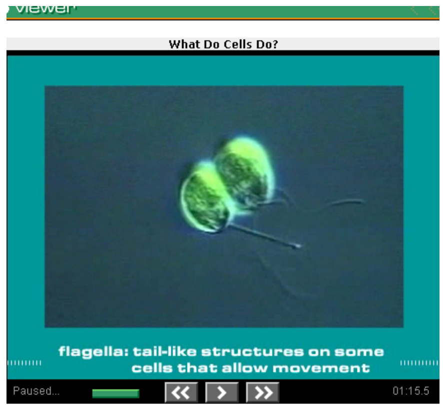


Figure 10: The cytoskeleton and flagella are introduced.

Self-Paced Media

In addition to animations, topics typically include one or more self-paced media pieces. These are intended as discussion supports for use by the teacher or by students who may use them in individual study — as they use the accompanying worksheet learning activities.

These media pieces often summarize key points and add detail to a topic introduced in an animation. For example, Figure 11 shows a review of parts of a bar graph in the context of an experiment that requires display of data in that form. Pulsing hot-spot buttons capture the critical features of the bar graph, and provide a way to "drill down" to additional detail, so the teacher can quickly stimulate recall on bar graph construction.

Figure 11: A slide presents an experiment requiring construction of a bar graph. After class discussion, the teacher can compare the class' bar graph with this model. Note the highlights on parts of the graph, used to direct attention.

Figure 12 is an example from a slide set in the World Cultures curriculum. This topic discusses how agriculture worked in the economy of ancient Egypt. Slides reveal as faces of a rotating “knowledge cube” that allows fast navigation through the information.

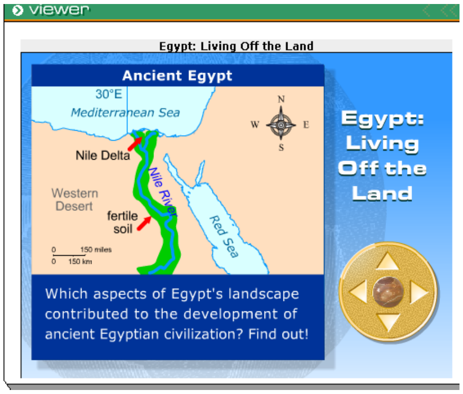


Figure 12: Slides on the agriculture and economy of Ancient Egypt.

In another example (Fig. 13), an interactive map first animates the routes of the explorers, and then offers students a chance to select hot spots on each route. Clicking on a hot spot drills down to greater detail on the explorer, the route, and the discovery.

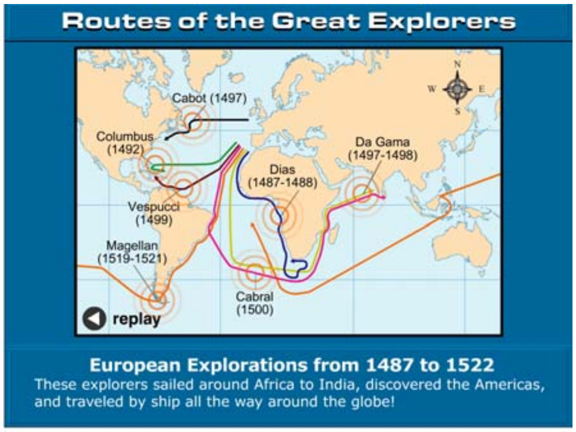


Figure 13: Animated routes of the explorers. Hot spots provide drill down to detail of each exploration.

The interactive, self-paced media pieces provide opportunities for students to make choices and explore the material in greater detail, while opening the door to further discussion on both right and wrong answers. An example of a typical drag-and-drop interaction is shown in Figure 14. In this interaction, students are asked to select cellular organelles used in photosynthesis to "construct" a plant cell. Clues are available to explain the name and function of each organelle.

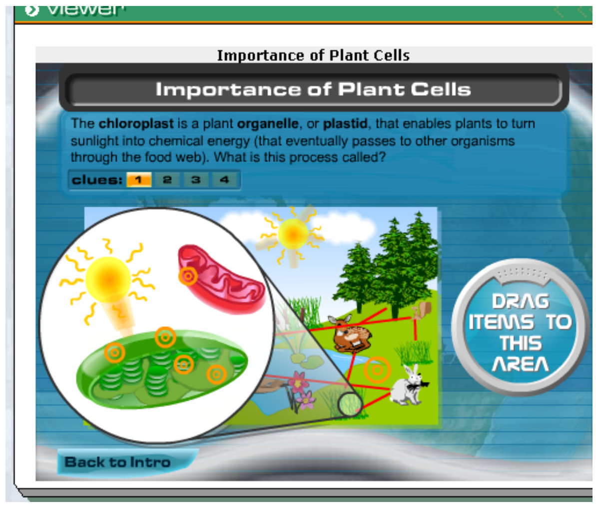


Figure 14: A drag-and-drop interaction helps build knowledge of plant cell function.

Another use of interaction is shown in Figure 15. In this example, students sequence the phases of mitosis. Moving the mouse over each card reviews its name.

Figure 15: Students sequence the phases of Mitosis in a drag-and- drop interaction.

The Curriculum On Wheels (COW)

No curriculum material has an impact if it isn't used. Ease of use and reliability are recognized as major issues in the spread of technology. In response to this problem, Ignite! Learning has developed a unique hardware platform to make using its software easy: the Curriculum On Wheels (COW). This is a self-contained unit that includes a projector and the entire social studies or science library. Just 5 buttons and a mouse are needed to navigate quickly to any resource. The buttons provide familiar controls for projection. No network connection is needed, and the complexities of a Windows™ interface, passwords, and network management are completely avoided. The COW is designed for use both in large-group instruction and individual study.

In sum, the Ignite! Learning curriculum provides a deep library of attractive multimedia learning activities for middle school science and social studies, which are aligned to standards and easily used by teachers — with a minimum of professional development.

Part 3 Research Underlying Ignite! Learning

Each of the key instructional features described in Part 2 represents the careful and systematic application of basic research on instructional design. Part 3 summarizes the research used in the design of Ignite! curricula.

Cognitive Structure: The Role of Ignite! Media

It's not just what you know but how you know it that counts. Current cognitive (brain-based) learning theory emphasizes the importance of teaching and learning knowledge structures (Anderson 1995), rather than teaching individual concepts in isolation. A generation of experimental evidence has demonstrated that knowledge is stored in memory and retrieved by way of its relationships to other knowledge. Furthermore, there is a very close relationship between how knowledge is used (or expected to be used) and what knowledge structure is in memory.

There are a number of important implications for effective instruction that come from this research. (Reigeluth 1999; Bransford, National Research Council [U.S.]. Committee on Developments in the Science of Learning. et al. 2000). Of particular interest here are two central principles of instruction:

- Teach the knowledge structure, as well as the components
- Keep the student oriented to the knowledge structure throughout the instruction.

The first principle suggests that effective instruction includes explanations, examples, and practice on how knowledge is related, as well as what the individual concepts are. A common technique is to create a graphic that shows the relationships among the knowledge components. The second principle suggests that knowledge structures are often useful as master graphics that the student can refer to throughout the learning process. This helps keep the student oriented to the "forest" of knowledge while studying each individual "tree."

In the Ignite! media pieces, this is a common technique. For example, Figure 16 (below) illustrates use of a master graphic that shows the sequence relationships of the steps in the nitrogen cycle. Each progressive slide adds detail, but the master graphic remains visible to keep the student oriented. Thus, the structure of the nitrogen cycle is always present, and it also is used as the menu structure for the presentation of this knowledge.

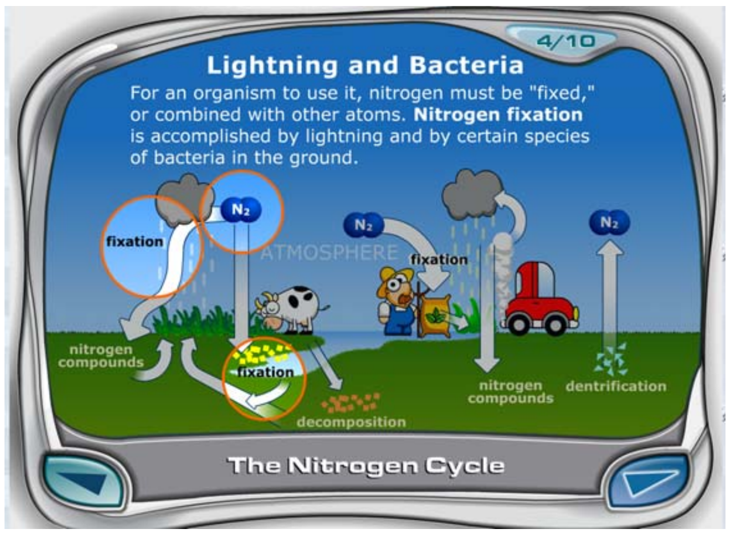


Figure 16: A master graphic shows the relationships between the steps of the nitrogen cycle. Each successive slide drills down to detail on each step in the cycle. The master graphic remains on the screen to keep the student oriented to the knowledge structure.

This attention to knowledge structures suggests that Ignite! media pieces can be used effectively throughout a lesson: at the beginning, the Ignite! pieces can introduce the knowledge structure and create an "empty" structure in the students' mind. Then in the lesson, as explanation and exploration of the knowledge structure builds understanding, Ignite! media pieces that show knowledge structure are available for constant reference. At the end of the lesson, returning to an Ignite! media piece is a useful way of summarizing and reviewing the knowledge structure represented.

Stories as Cognitive Structures in Ignite!

Current brain research has also led to an improved understanding of the role of experiential memory: your memory of things you have done. Theorists have argued that experiential memory may be organized as stories: sequences of events done by actors (Golden and Rumelhart 1993; Schank and Abelson 1995). If this is the case, they argue, then telling stories is an important part of instruction because stories are particularly easy to encode into memory and retrieve. The structure of the story itself may provide scaffolding that is useful to the student (much as the structural elements of music have been shown to scaffold memory of the lyrics).

Stories are often incorporated into Ignite! media pieces. The pieces feature characters with names and personalities, and the characters enact a story that has a meaningful beginning, middle, and end, with the key defining characteristics of narrative. This technique is particularly useful in social studies. An example is the story of the XYZ Affair of 1803 (an early example of America asserting itself diplomatically, in this case with France), shown in Figure 17. The story tells how three diplomats went to France to negotiate an end to intimidation by the French Navy, and successfully struck a deal to avoid war without resorting to bribery.

Figure 17: The story of the XYZ Affair, in the form of an operetta.

Multimedia in Ignite!

There is considerable experimental evidence (Hortin 1983; Mayer and Moreno 1998; Mayer 2001) that the combination of words and pictures is particularly powerful in instruction. A recent review of research (Clark and Mayer 2002) concluded:

> …people who learned from words and graphics produced between 55 percent and 121 percent more correct solutions to transfer problems than people who learned from words alone. Across all studies, a median percentage gain of 89 percent was achieved with an effect size of 1.50.

This is powerful research-based validation of the old adage that "a picture is worth a thousand words." In teaching and learning, we can show that an informative picture and relevant words are worth about 89% more than words alone. This is one of the strongest effects of any instructional design variable.

Here we have one of the major reasons for the power of Ignite! Learning media pieces, which use animation and audio. Because the media pieces include a visualization of key information relevant to the learning objective, and when words describe what is happening visually, then this powerful learning effect occurs. This combination often is found in Ignite! Learning media pieces. There is accumulating evidence on why this effect is so powerful, and why it is particularly important for students with limited learning skills. The evidence comes from recent work on Cognitive Load Theory, done by Sweller and others (Clark, Nguyen, et al. 2006). The essential principle of this theory is that "information overload" is a serious constraint on learning and performance: the human brain has huge storage capacity, but extremely limited ability to process chunks of information simultaneously.

Experimentally, the limit has been shown to be 7 ±2 chunks of information for students from age 11 on (and in many circumstances, the limit is probably closer to 5). Since, as we discussed above, learning always involves forging links among chunks of information, the basic act of comprehending and learning involves perceiving new information and holding it in "working memory" until it can be interpreted and linked with existing knowledge in a meaningful way. It is very easy to inadvertently overload this process by simply providing too many chunks of information at once.

How you present the information turns out to be critically important to its impact on cognitive load. Reviews of experimental research on verbal, auditory, and visual comprehension (Mayer and Moreno 1998) have led to the conclusion that there is only one channel for verbal processing, whether read or heard, and another channel for image-based information. This means that it is most effective to present images visually and to explain them in audio. If words are in the image at all, they should be limited to a few labels or short phrases that are identical to and closely synchronized with the words in audio. Including an extensive text explanation with the visual actually competes for processing power with the words in audio, with the net result that learning efficiency declines.

Close examination of the Ignite! media pieces that combine animation and sound show application of design principles consistent with cognitive load theory. As a general rule, the amount of text on screen in animations is kept to an absolute minimum — key words and labels. The on-screen text is synchronized tightly with the use of the same words in audio, and most of the explanation occurs in audio, which is closely and meaningfully tied to each move in the animation. When large amounts of text are needed, they are included in the self-paced media pieces with no sound, so as not to present conflicting channels of verbal information. By self-pacing these media pieces, overload of verbal comprehension capacity is prevented.

Music in Ignite!

Teachers, like advertisers, have observed that music helps make things memorable. This effect has been confirmed by research (Wallace 1994). In a landmark series of experiments, Wallace demonstrated that better recall of text results when it is structured as multiple verses to the same melody, than when text is presented alone or when a different melody is used for each verse. Additional experimentation demonstrated that the structure of music adds emphasis well beyond rhythm. Wallace concludes:

> Music is a rich structure that chunks words and phrases, identifies line lengths, identifies stress patterns, and adds emphasis as well as focuses listeners on surface characteristics. The musical structure can assist in learning, in retrieving, and if necessary, reconstructing a text. (p.1471)

This research confirms the power of music in Ignite! media pieces. Many of the animations use music with informative lyrics to tell stories and to introduce key terms. The music is in popular idioms such as rock, rap, and country/western, which are appealing and easily accessible by young teen students, contributing to the songs' memorability. Following the research guidelines, the songs are typically organized in verses with a repeating melody, and use formal elements such as rhyme to add further to structure and memorability. The result is that the songs aid in learning key terms and stories (especially useful in social studies) and then facilitate retrieval and, if necessary, reconstruction of the words and stories at a later date.

An example is shown in Figure 18. Here, a catchy rock tune brings to life the story of Hatshepsut, the first woman Pharaoh, by presenting the story with a distinctly feminist theme designed to be meaningful to millennial students. Each verse outlines the Pharaoh's accomplishments, and the refrain is that, after a long heritage of male Pharaohs, "Hatshepsut has evened the score!"

Figure 18: A singing sphinx joins the chorus of a catchy rock tune on the accomplishments of Hatshepsut, the first woman Pharaoh.

Motivational Strategies in Ignite!

Teachers are acutely aware of the primary importance of motivation in learning, and any successful teacher has a valuable collection of motivational techniques for the classroom. As discussed in Part I, the needs of contemporary young teens represent a unique challenge. Their brain development is in transition from childhood to adulthood, and their tendency is to seek experiences that present excitement, and which appear to require little effort (have a high probability of success). Goal-directed motivational appeals (along the lines of "if you work hard you can achieve this career goal") are effective with older students, but they are much less effective with young teens. Furthermore, the children of the Millennial generation present a very different profile from earlier generations: they tend to value learning, and they are used to having a world of information and communication instantly available — literally — at their fingertips.

Current motivation theory includes three distinct types of motivation: interest, confidence, and concentration (Keller 1987; Mayer 1998; Clark, Nguyen, et al. 2006). *Interest* is the belief that attending to the learning task at hand is worthwhile. For contemporary young teen students, *interest* usually results from a promise of excitement and novelty. *Confidence* results from the belief that the learning task offers a promise of success with an acceptable level of effort. If the learning task is perceived as too difficult, then it serves as a deterrent — especially for students of this age, as discussed above. Interestingly, if the task is perceived as too easy, then overconfidence can result, leading to a lower probability of success.

The importance of *concentration* has emerged as an important motivational effect from Sweller's Cognitive Load Theory. In an extensive series of experiments (a useful summary is in Sweller 1990), Sweller has demonstrated that students split their limited cognitive processing resources among multiple tasks, depending on their judgment of the worth of the task — in other words, motivation. The student who is simultaneously reading a textbook, listening to rock music, and IM'ing friends is allocating cognitive resources according to their worth — and textbook learning is the loser. A more interesting and motivational instructional strategy will succeed if the student feels the task deserves a greater allocation of cognitive resources.

It should now be clear why the motivational effects of Ignite! media pieces are so critical, and so well suited to contemporary young teen students. The lightly humorous style of the animations, the use of appealing music, and the self-paced information-on-demand available via drill down, are all carefully designed to build interest, confidence, and concentration in ways that will effectively compete for the students' attention and cognitive resources — whether in large-group, small-group or individual use. Far from trivializing the message of the content, it is precisely these motivational strategies that are a major reason for the success of Ignite! media pieces.

The extensive library of Ignite! media pieces is a unique and valuable teaching resource for young teen science and social studies. The Ignite! multimedia and their accompanying worksheets apply many research-based "best practices." Of particular importance is the design of instructional messages to promote motivation and to build appropriate cognitive structures and memory. This is done with a careful understanding of the frame of reference and cognitive processing characteristics of contemporary young teen students.

Part 4 Deepening Understanding with Reality, Inc.

It is not enough to recall terms and their definitions, or to give examples of concepts. Full understanding depends on the student's success in constructing a fully connected knowledge structure (schema) that includes all the dynamic relationships between its components. Constructing this kind of knowledge structure is best done by requiring the student to *observe and predict* the behavior of systems, or to *explain* why they behave as they do. These abilities are the landmark of *principle* learning, and they are the best indicator of deep understanding. Building deep understanding is the purpose of the Reality, Inc. series of science activities.

Each activity in the curriculum uses a common structure.

1) An introductory scenario challenges the students to predict or explain the behavior of a system of scientific interest. In this example (Fig. 19), a customer has paid to breed his shorthaired cat with another one, but the offspring (Marzipan Squishyface) is longhaired. The customer complains, and Mortimer Gravitas challenges the student to determine if there are grounds for the complaint.

Figure 19: Mortimer Gravitas challenges the student to find out if Marzipan Squishyface's long hair is possible, if Marzipan is the offspring of two shorthaired cats.

In the research section, an “ask the expert” activity explains the key concepts involved in understanding the problem. In this example, Mortimer Gravitas’ wife, Carol, happens to be a geneticist who can explain the terminology of basic genetics. Students can gather additional information in the Research Area, and learn how to construct their own Punnett Squares, the technique commonly used to explain the possible genetic outcomes of combinations of alleles (Fig. 20).

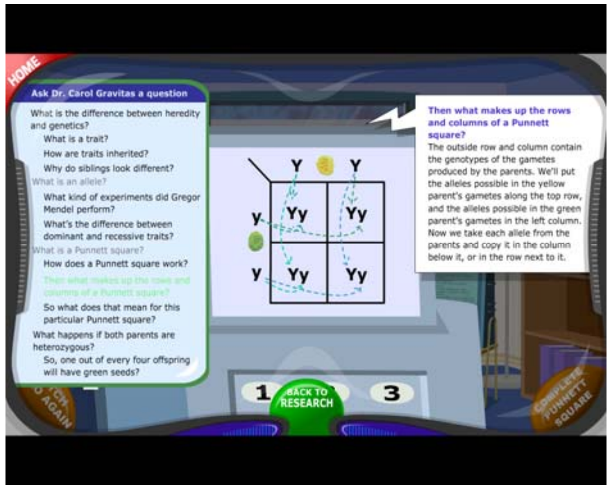


Figure 20: Dr. Carol Gravitas explains genetic concepts, and construction of a Punnett square.

Additional information is presented in a song. In this example (Fig. 21), the rock group The Alleles explains the difference between genotype and phenotype, one of the core concepts of genetics. Since the two terms are easily confused in memory because of their similarity, use of a song to explain them is particularly useful because it adds extra scaffolding to help the student keep the terms straight.

Figure 21: The rock group The Alleles give the students a memorable way to keep straight the difference between phenotype and genotype and introduce other key terms in genetics.

2) In an activity section, students apply what they know. In this example, (Fig. 22), students construct a Punnett square to see if Marzipan Squishyface's long hair could result from two short-haired parents. In this way, they explain how the observed phenomenon of long hair occurred, thus deepening their understanding of genetics.

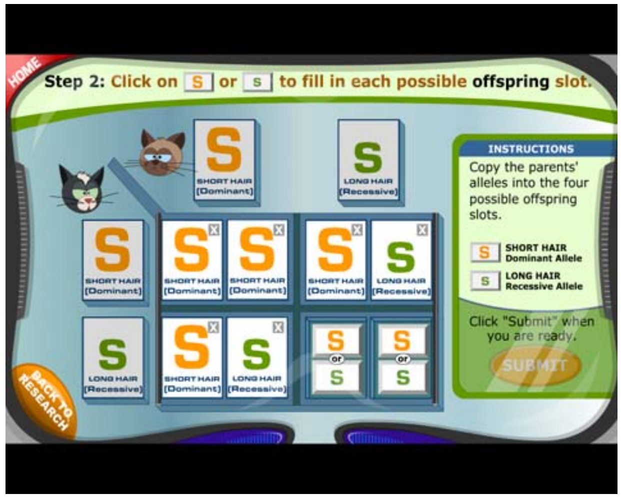


Figure 22: Students construct a Punnett square to find out if Marzipan Squishyface's long hair could result from two shorthaired parents. First, the students label the rows and columns with symbols for the dominant and recessive alleles, and then they complete the square by filling in the possible genetic combinations and their expression as long or short hair. Students report to Mortimer Gravitas that Marzipan Squishyface simply inherited two copies of the recessive gene for long hair.

Other problems in the curriculum use other devices to build understanding. For example, in a problem on simple machines, students are challenged to build a Rube Goldberg-like network of simple machines to help monkeys get bananas (Fig. 23) by dragging and dropping the appropriate machine to each position. Students can check the result by activating the machine and seeing if the monkeys reach the bananas or fall short.

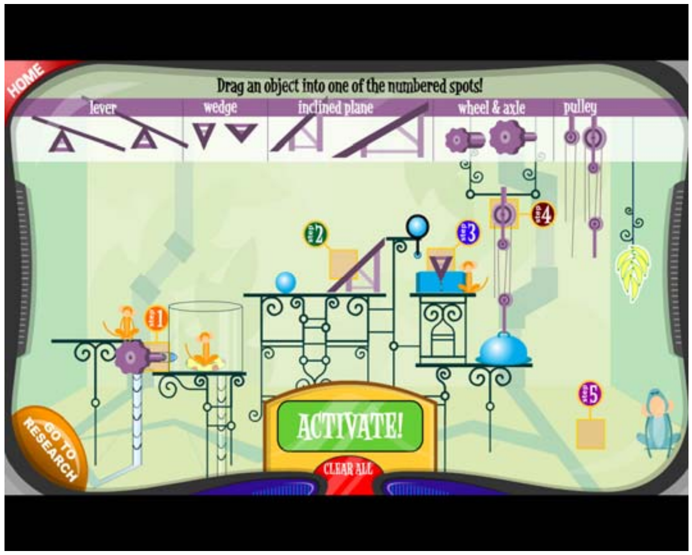


Figure 23: Students build a network of simple machines, each of the right size, to help the monkeys get the bananas. Step 5 still needs the right lever for the network to be complete.

In other scenarios, a variety of other techniques are used. For example, some scenarios challenge students to judge if an explanation makes sense or to spot common misconceptions about how systems work in nature.

Recent research has shown the value of activities such as these in building deep understanding of science (for a review of well-researched techniques, see Stepans 1994). In particular, activities that require students to build models and then observe, predict, or explain their operation have been found to be effective. Exploiting online modeling technology, as in the example above, offers particular power. In addition, research on misconceptions in science has demonstrated that students acquire misconceptions early and retain them into the college years if they are not specifically addressed (Beatty 1996). This helps demonstrate the value of the misconception-probing activities in Reality, Inc., particularly those with rich explanatory feedback.

Part 5 Implementation as a Mediator of Technology

As technologies have become increasingly available in schools, it has become clear that simply making a technology available does not assure its effective use by teachers. Investigations of the reasons why some technologies succeed in some schools but not others, is leading to a much more complete understanding of the critical success factors for introducing technological innovation into schools. Hodas (2005) argues that "no technology is ever neutral: that its values and practices must always either support or subvert those of the organization into which it is placed; and that the failures of technology to alter the look-and-feel of schools frequently result from a mismatch between the values of school organization and those values that are embedded within the contested technology itself."

All too often, technologies fail in schools because their design assumptions do not fit the patterns of use, resources, and capabilities of schools and teachers — in short, the culture of the classroom. Teachers often correctly perceive that technologies are complicated because they require more time and effort to understand and to use than is typically available in the daily and weekly crush of work — preparing lessons and attending to the individual needs of hundreds of students. A technology that requires a substantial "learning curve" is likely to gather dust in the closet rather than making a useful contribution to the daily work of the classroom.

Furthermore, studies sponsored by the Consortium for School Networking (Fitzgerald and Kaestner 2004; Networking 2004) have demonstrated that the indirect costs of technologies, including technical support and professional development, often far exceed the original purchase costs. Yet schools rarely budget adequately for these indirect costs. A common result is that the technology implementation is weak: teachers are not adequately trained or the technology itself is inadequately installed and implemented. Regardless of the real cause, teachers perceive the technology as unreliable, untrustworthy, and not worth the effort.

It is perhaps most common to view this outcome as the result of inadequate resources and effort on the part of schools and teachers. But there is another, alternative view: perhaps the problem is, as Hodas argues, that the core design assumptions of the technology are inconsistent with the requirements of schools.

A simple analogy will help to illustrate the point: computers have found their way into automobiles and commercial jet aircraft, but in those applications the engineers have understood the need for a degree of user simplicity and reliability not found in common personal computers (after all, when was the last time you had to enter CTRL-ALT-DEL to get your car started? Or your TV? When was the last time you needed days of professional development to operate your telephone?). Perhaps the problem is that technologies adapted from the office desktop are based on design assumptions that are not a good fit for the classroom.

This is a crucial point in understanding the significance of Ignite! Learning and the Curriculum On Wheels (COW). The COW's design is entirely self-contained, designed as a compact, freestanding projection unit that can be easily positioned anywhere in a classroom. Basic operations use power, play/stop, and fast-forward/rewind buttons with the same standard labels found on VCRs and tape recorders. A mouse is used to navigate a simple menu system that provides access to any Ignite! media piece with a minimum of mouse clicks. There is no administrative overhead to manage logins, passwords, classes, and rosters. No network connection is required, and there are no concerns about security, viruses, or access to unauthorized content. In short, the Ingnite! COW is designed to preclude nearly all of the potential sources of high indirect costs for technical support of technology.

The Ignite! curricula show a similarly deep insight into the requirements of real teachers in real classrooms. The menu system teachers use to access the curriculum materials is extremely simple, using standard topic names that correspond well to those used in most textbooks. The result is that aligning the Ignite! curricula to the daily lesson can be done using a few mouse clicks; there is no need for a separate curriculum management system.

The curriculum materials themselves have been carefully designed so teachers can instantly see how to best use them in the classroom. The materials are designed to fit into the normal structure of a lesson, with short presentation and interactive components followed by discussion, and supported by individual or small group seatwork. The materials thus are designed to enrich teaching and learning and to reinforce, rather than displace, the rhythms of the classroom-learning environment.

The net result is that this is a technology which teachers can grow comfortable with in a matter of minutes or hours — not days or weeks. It is reliable and places no extra load on the technical support or networking resources of the school. No technology has benefit unless it is used; Ignite! Learning's technology will be used constantly.

Part 6 Concluding Remarks

The requirements of young teen learners are unique. Cognitively and motivationally they are quite literally in transition from childhood to adolescence. Furthermore, today's young teens are the second wave of what has been called the Millennial Generation — individuals who have made a marked departure in social norms, expectations, and learning habits from their older "Generation X" siblings. As a result, curricula designed for them have unique requirements. Unfortunately, most materials used in the middle grades are merely adaptations of lower elementary or upper high school curricula, and they do not reflect these unique needs.

The Ignite! Learning approach distinguishes itself as one of the very few technology-based curriculum supplements designed from the ground up to meet the needs and learning habits of today's young teen students. Its principal instructional features include:

- Learner-appropriate overviews to frame and reinforce cognitive structures of key curriculum topics, designed to aid retention by using full multimedia with animation, instructional graphics and illustrations, and music
- Detailed explanations and explorations in self-paced interactive formats
- Motivational style and message designed to appeal specifically to young teens, to gain their attention and concentration
- Interactive problems and games to build deep understanding of science
- Supporting worksheets and unit tests.

These learning activities are packaged in a highly modular topical form to permit maximum flexibility in integrating them into the curriculum.

The sophistication of Ignite! Learning solutions are masked by their apparent simplicity. Ignite! animations are no more than 3 minutes long, yet they convey a great deal of information through carefully designed graphics, verbal explanations, and songs. The interactive, self-paced media pieces are carefully designed to reinforce key points and to build deep understanding. There is a high degree of alignment among the components of the Ignite! Learning experience, so the benefits to learning accumulate and intensify as students move from one learning activity to the next within each topic.

The Ignite! Learning experience is a premier example of a new generation of educational technology. It is designed from the ground up, both hardware and software, specifically for the needs of real teachers in real classrooms. It is not a "force fit" into the classroom of technologies originally conceived for offices or homes. The end result is a technology that is easily understood and incorporated into the structure of the classroom, and one that places little or no load on the technical support and networking resources of the school. It is a technology investment that will really be used, by real teachers, in real classrooms.

References

Anderson, J. R. (1995). Learning and memory: an integrated approach. New York, Wiley.

Beatty, W. J. (1996). K-6 Textbooks and "Science myths" in Popular culture, The Science Hobbyist.

Bransford, J., National Research Council (U.S.). Committee on Developments in the Science of Learning., et al. (2000). How people learn: brain, mind, experience, and school. Washington, D.C., National Academy Press.

Casey, B. J., N. Tottenham, et al. "Imaging the developing brain: what have we learned about cognitive development?" Trends in Cognitive Sciences **9**(3): 104-110.

Clark, R. C. and R. E. Mayer (2002). E-Learning and the science of instruction: proven guidelines for consumers and designers of multimedia learning. San Francisco, CA, Jossey-Bass Publishers.

Clark, R. C., F. Nguyen, et al. (2006). Efficiency in learning: evidence-based guidelines to manage cognitive load. San Francisco, Jossey-Bass Publishers.

Education, U. S. D. o. (2004). Toward A New Golden Age in American Education: How the Internet, the Law and Today's Students are Revolutionizing Expectations. Washington, D.C., U.S. Department of Education**:** 65.

Fitzgerald, S. and R. Kaestner (2004). Rational Spending: A Closer Look at Total Cost of Ownership. COSN Compendium 2004, CoSN.

Giedd, J. N., J. Blumenthal, et al. "Brain development during childhood and adolescence: a longitudinal MRI study." Nature Neuroscience **2**(10): 861.

Golden, R. M. and D. E. Rumelhart (1993). "A Parallel Distributed Processing Model of Story Comprehension and Recall." Discourse processes **16**(3): 203-238.

Gonzales, P., J. C. Guzman, et al. (2004). Highlights from the Trends in International Mathematics and Science Study (TIMSS), 2003e. NCES 2005-005, ED Pubs, P.O. Box 1398, Jessup, MD 20794-7827. Tel: 877-43-7827 (Toll Free). 119.

Hodas, S. (2005). Technology Refusal and the Organizational Culture of Schools, 2.0.

Hortin, J. A. (1983). Experiencing the image: visualizations role in educational technology, Paper Presented At the 1983 Association For Educational Communications and Technology Convention in New Orleans.

Howe, N. and W. Strauss (2000). Millennials rising: the next great generation /by Neil Howe and Bill Strauss; cartoons by R.J. Matson. New York, Vintage Books.

Howe, N., W. Strauss, et al. (2003). Millennials go to college: strategies for a new generation on campus: recruiting and admissions, campus life, and the classroom. [Washington, D.C.], American Association of Collegiate Registrars and Admissions Officers.

Keller, J. M. (1987). Development and use of the arcs model of instructional design, Journal of Instructional Development.

Mayer, R. E. (1998). "Cognitive, Metacognitive, and Motivational Aspects of Problem Solving." Instructional Science **26**(1-2): 49-63.

Mayer, R. E. (2001). Multimedia learning. Cambridge; New York, Cambridge University Press.

Mayer, R. E. and R. Moreno (1998). "A Split-Attention Effect in Multimedia Learning: Evidence for Dual Processing Systems in Working Memory." Journal of Educational Psychology **90**(2): 312-20.

Networking, C. F. S. (2004). Taking TCO to the Classroom. T. G. Group, Consortium for School Networking.

Proverbio, A. M. and A. Zani "Developmental changes in the linguistic brain after puberty."

Reigeluth, C. M. (1999). The elaboration theory: Guidance for scope and sequence decisions. Instructional-design theories and models. C. M. Reigeluth. Mahwah, NJ, Lawrence Erlbaum Associates. **II**.

RoperASW (2002). National Geographic-Roper 2002 Global Geographic Literacy Survey. Washington, D.C., National Geographic Education Foundation.

Schank, R. C. and R. P. Abelson (1995). Knowledge and memory: the real story. Knowledge and Memory: The Real Story. Hillsdale, NJ, Erlbaum. **8:** 1-85.

Spear, L. P. "Neurobehavioral Changes in Adolescence." Current Directions in Psychological Science **9**(4): 111-114.

Stepans, J. (1994). Targeting students' science misconceptions: physical science activities using the conceptual change model. Riverview, FL Idea Factory, Inc.,

Sweller, J. (1990). "Cognitive Processes and Instruction Procedures." Australian Journal of Education **34**(2): 125-30.

Wallace, W. T. (1994). "Memory for music: Effect of melody on recall of text." Journal of Experimental Psychology / Learning, Memory & Cognition **20**(6): 1471.