Summer Report 2011

Design & Development

Designing a Platform for Critical Thinking in Biology Education

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Carnegie Mellon University

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Executive Summary

Background

In education today, more and more technology, such as SmartBoards, laptops, and electronic textbooks, are being integrated into classrooms in the hopes that this technology will create a more engaging and productive learning environment for students. With increasingly novel ways of delivering content to students, as well as more advanced artificial intelligence, technology can better address aspects like engagement, intrinsic motivation, and evolving content with constantly changing curricula. As graphing calculators did for math, technology now has the potential to eliminate menial tasks and facilitate higher levels of critical thinking in other school subjects such as biology. This level of critical thinking, constantly emphasized by educators as a top priority to instill in students, becomes more feasible with the help of well-designed technology.

However, while technology is inherently engaging, simply adding any technology to the classroom will not guarantee an educational advantage. As our literature review from last semester suggests [Spring Report], there are several factors that play into whether technology will be beneficial in the classroom. These factors include whether or not the technology incorporates any pedagogical value, whether teachers need to be trained, and characteristics inherent to technology that are both positive and negative. In order for technology to reach its educational potential, it must account for these factors and satisfy the needs of teachers and students.

Inquire: Biology

In an effort to engage students and increase learning in biology students, SRI International along with Vulcan Inc. developed an electronic textbook called Inquire: Biology. What sets this electronic textbook apart from its competitors is that it integrates knowledge representation and reasoning technology. This technology, known as the Automated User-Centered Reasoning and Acquisition System (AURA), allows high school students to pose Advanced-Placement style questions and get user appropriate explanations. At the beginning of this year, SRI established a working relationship with students from CMU to perform ethnographic studies and design a new application to take advantage of this advanced technology to enhance biology learning.

Spring Research

Our interdisciplinary team of four Master's students from Carnegie Mellon University's Human-Computer Interaction Institute set out to understand the learning dynamic that occurs between teachers and students in biology classrooms and how AURA could enhance this dynamic. Our four month research phase from January to May 2011 uncovered three important elements of biology learning that should be taken into consideration when designing new technologies:

1. Presenting content with the proper amount of scope,
2. Giving adequate feedback and assessment to help students progress, and
3. Allowing an easy way to search and discover relevant information.

We also discovered a model of learning we call the Learning Cycle, which encompasses the techniques teachers use in the classroom, students' methods of studying, and testing in the classroom.

Design Focus

Upon completing our research in this domain, we held a visioning session with SRI to settle on a design focus for the next phase of our project. SRI and our team both agreed that focusing on designing a solution that implemented Socratic Questioning would be interesting and would also appropriately utilize AURA. Socratic Questioning seeks to get a person to answer their own questions by making them think and draw out the answer. As a teaching technique, it prompts student thinking by continually asking questions and consequently gives teachers feedback on what the student needs help with. Socratic Questioning serves as an extremely powerful method of exploring complex ideas, revealing false assumptions, and freely analyzing concepts. Through further focused research and ideation, this design direction evolved into an idea that prompts critical thinking by encouraging students to directly engage with the content generated by AURA.

Design Solution

We call our design solution Thinkspace. As a tool meant to help students answer complex synthesis questions, Thinkspace enables students to bring relevant information into a single space, formulate their thoughts, and synthesize the information into a coherent answer. More concretely, Thinkspace provides a blank canvas to which students can search, add, and manipulate content generated by AURA. Our solution encourages a higher level of critical thinking by providing a variety of information and a platform for students to synthesize larger ideas. By providing free-form, direct interaction with this platform, Thinkspace engages students in the work of biology learning.

This report details our solution (page 21), design process (page 43), and vision for the future of Thinkspace (page 75).

Table of Contents

Introduction

As part of the Master's program in Human-Computer Interaction at Carnegie Mellon University, a team of students collaborated with SRI International to design and develop a new technology application to engage and enhance learning in biology students.

This section details our work from last semester that led to our design focus of Socratic Questioning in the design phase and an introduction into our work over the summer.

Project Background

SRI International, the client for this project, is a major non-profit research institute based in Menlo Park, California. Since 1946, SRI International has made major scientific discovery and contribution towards the application of science and technology for knowledge, commerce, prosperity and peace.

Together with **Vulcan Inc.**, SRI International is working towards an ambitious vision to represent the world's scientific knowledge in a queryable knowledge base.

In 2003, **Project Halo** began the effort to build this vision with a system capable of representing and retrieving the world's knowledge via natural language questions. At the current phase of the project, SRI International is working towards integrating biology content into the knowledge base.

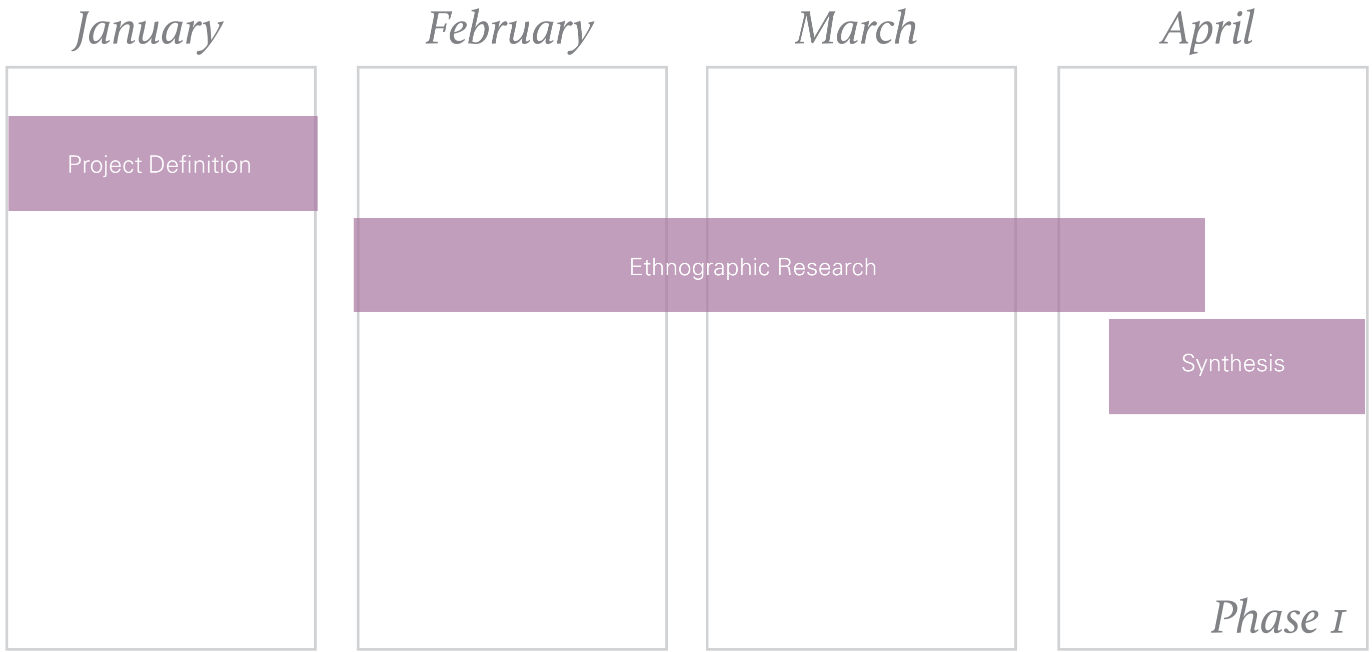
As part of the current work of representing biology knowledge, SRI International created **Inquire: Biology**, an iPad based electronic textbook with the ability for students to ask questions and retrieve answers from the textbook. Inquire: Biology is powered by the **Automated User-Centered Reasoning and Acquisition System (AURA)**, which provides the technology behind natural language reasoning and knowledge retrieval.

Team Halo is the Carnegie Mellon University team from the Master's of Human-Computer Interaction Program tasked to investigate what educational contexts this technology would be most valuable and to provide a high-fidelity prototype that leverages the Halo technology.

Project Statement

To understand the study habits of AP biology students and the role of technology in the classroom in order to create a solution demonstrating Halo technology that supports teachers and engages students.

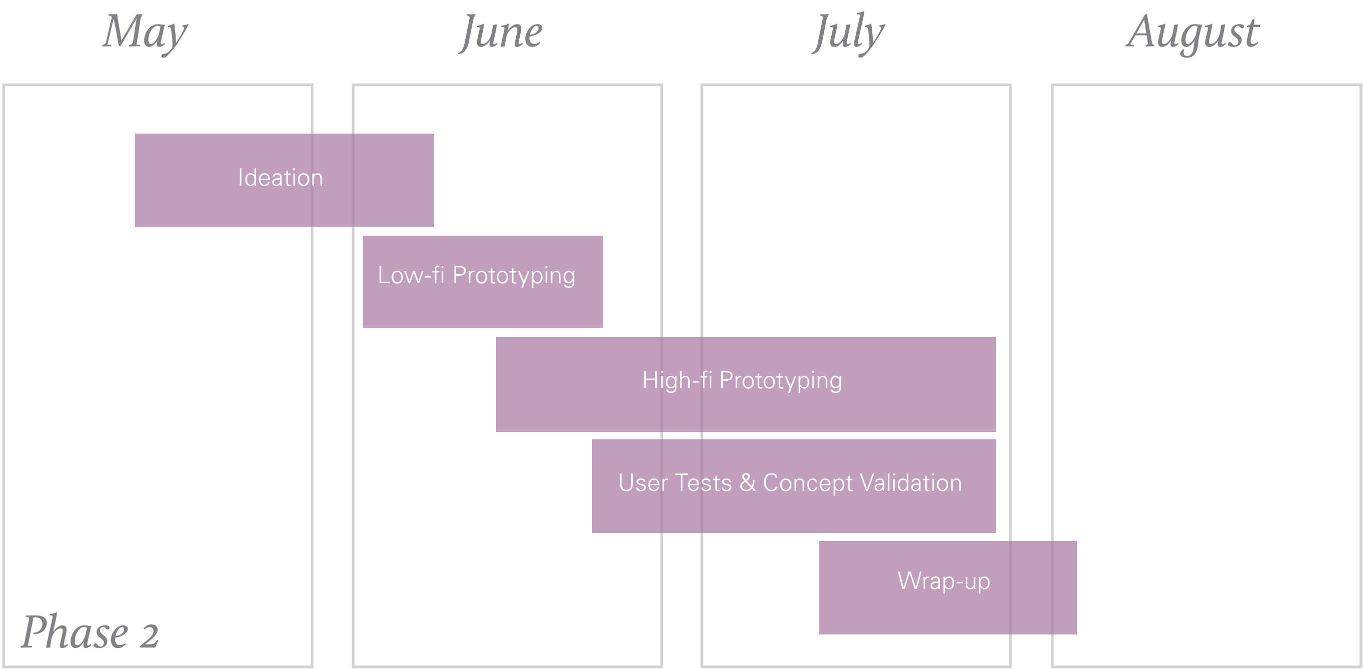
Project Schedule



The project is divided into two phases.

The first half of the project consists of ethnographic studies conducted on students and teachers in Spring 2011. For more information on the first part of the project, please refer to the report titled: Implications of Technology Integration in Biology Education.

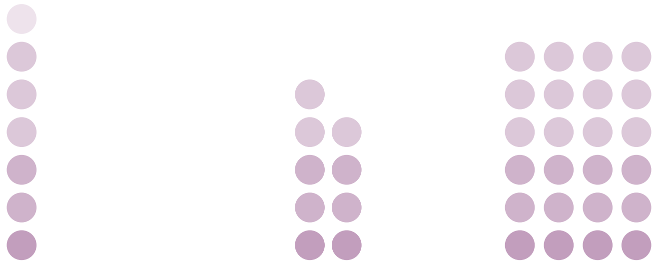
This report details the work done on the second phase of the project which includes the process and design of the prototype.



Spring Research

Our ethnographic research began early in the year and spanned a duration of four months.

With the end goal of designing an application that successfully integrates artificial intelligence with biology education, our team needed to understand the current dynamic between biology students and teachers. To this end, we employed user centered design methods, as detailed below, to reveal important aspects about teacher strategies and student habits in biology classes. The results of our research, detailed in our Spring Report, informed and heavily grounded our design solution in contextual research.



7 High Schools

9 Teachers

24 Students

Contextual Inquiry

By observing teachers and students in the context of the classroom, we built a better understanding of the strategies teachers use, such as Socratic Questioning, as well as the ways students interact in a classroom setting.

Diary Studies

We gave out 19 diaries to students to track their use of study materials over the course of a week. Using their entries, we found out how resources are utilized in their day-to-day studies.

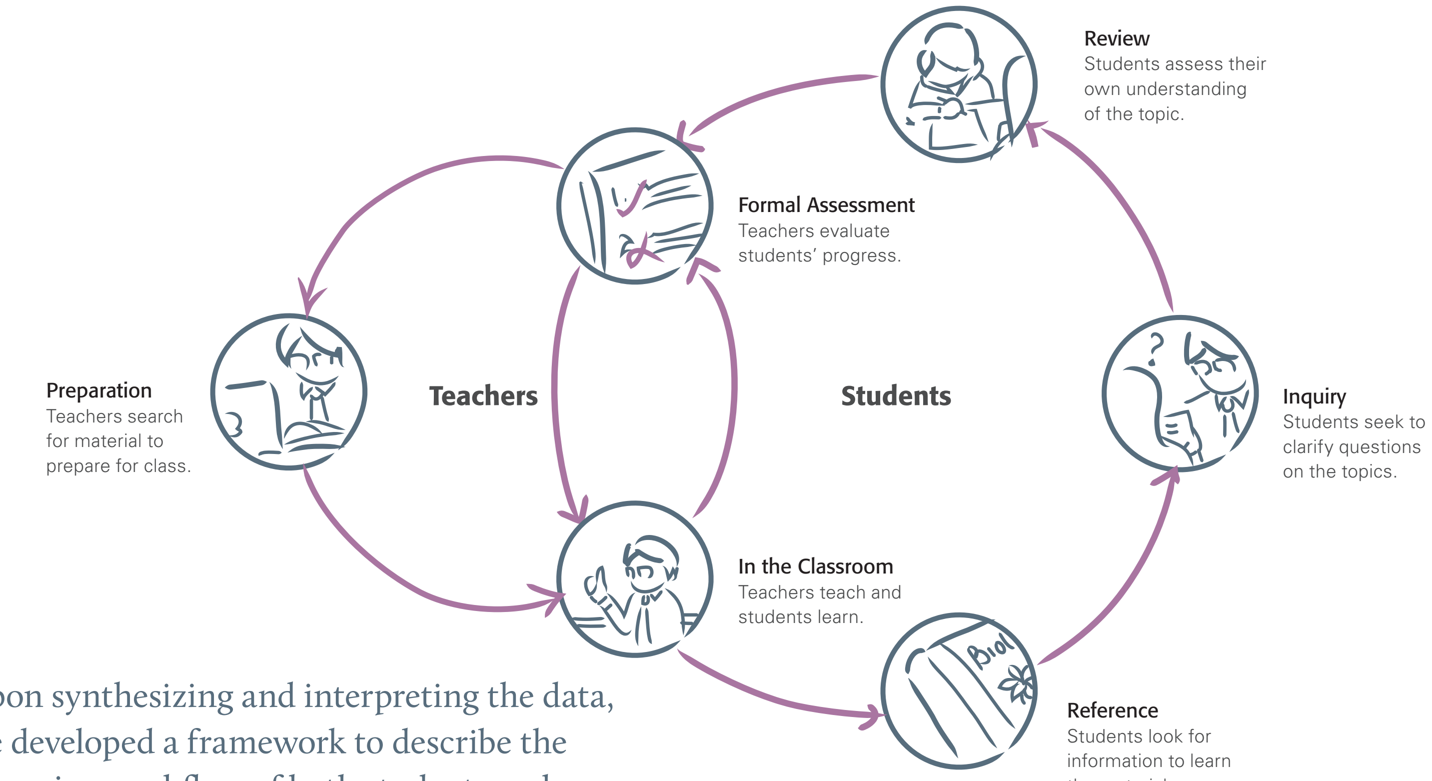
Interviews

We spent the majority of our time talking face-to-face with teachers and students first finding out from teachers how they teach biology and the technology that they use, then students about how they study and prepare for biology.

Surveys

Using a survey, we quickly gathered teachers' sentiments on their current technology use in classrooms as well as the technology that they wish to use in classrooms.

The Learning Cycle

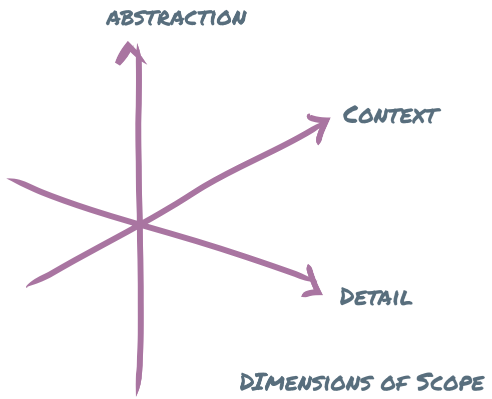


Upon synthesizing and interpreting the data, we developed a framework to describe the recurring workflow of both students and teachers called the Learning Cycle.

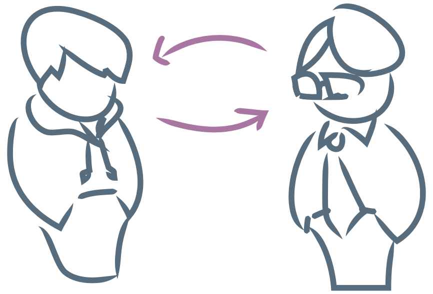
This cycle describes the various activities both students and teachers partake to achieve the goal of learning the material, and teaching the material well.

Cross-Cutting Themes

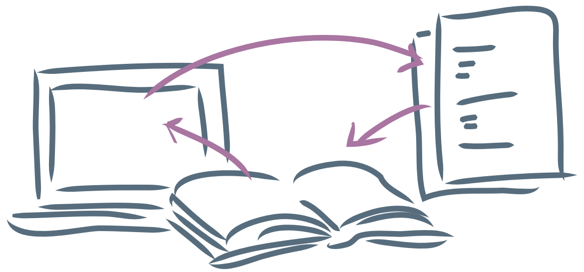
In addition, we identified three cross-cutting themes that underline the concerns both students and teachers have about biology education. We concluded that any solution attempting to integrate with biology education today should take these themes into account.



Scope generally refers the level of abstraction, context, or detail the content is presented with. We drew an analogy to photography: (1) abstraction can be likened to the blurriness of a photo, (2) context can be likened to a photo's crop, and (3) detail can be likened to the level of zoom of a picture. Scope serves as an important aspect in teaching the most relevant content necessary to advance a student's progress in learning. When the wrong amount of abstraction, content, or detail is used, students don't understand the information they require.



Feedback & Assessment are beneficial to both teachers and students alike. Students require feedback to assess their own performance to improve in areas they are lacking. Teachers require feedback to assess their students' learning progress in order to scope and pace the class accordingly. They also need to assess students so that they can adequately challenge their students to maximize learning.



Search emerged as an important theme that addresses how both students and teachers use various materials to find the information they need to complete their tasks. Depending on the task, which ranged from answering homework questions to finding teaching material, different forms of media are used. Electronic methods are used for its immediacy and vastness of information while more traditional forms of paper are useful in terms of scope and accuracy. Because various media are used, teachers and students often struggle to find a way to synchronize all the information into one space.

Visioning Session

We chose to narrow the focus of the design phase to address the most engaging issues in biology education and also to appropriately utilize and showcase AURA.

To this end, our team conducted a visioning session with SRI in which we articulated the key themes of our research and brainstormed several design solutions[1] that addressed them. From this visioning session, we generated a number of ideas that utilized SRI's knowledge base and reasoning technology and as well addressed our key findings from spring.

In the visioning session, we eventually settled on Socratic Questioning as our design focus for the summer.

Teachers currently use Socratic Questioning[2] as a technique to prompt student thinking by asking questions. In his paper *The Socratic Method: Teaching by Asking instead of by Telling,* Rick Garlikov[3] explains that the Socratic Method is in *its purest form, where questions (and only questions) are used to arouse curiosity and at the same time serve as a logical, incremental, step-wise guide that enables students to figure out about a complex topic or issue with their own thinking and insights.*

Design Focus: Socratic Questioning

1 A list of these solutions can be found in the appendix.

2 Further elaboration on Socratic Questioning can be found in our Spring Report and in the Focused Research section of this report.

3 Garlikov, Rick. "Richard Garlikov." The Socratic Method:. 27 Apr. 2008 <http://www.garlikov.com/Soc_Meth.html>.

How does Socratic Questioning address our three cross-cutting themes?

Scope

By asking the right questions, students can properly scope their search for information. Questions like "How does A cause B?", for example, helps students better understand that the problem they are trying to solve involves elements A, B, and the process in between. Teachers consistently use Socratic Questioning to help students focus on the relevant concepts related to a hard question.

Feedback & Assessment

In the most traditional usage of the technique, Socratic Questioning serves as a powerful way for teachers to evaluate student knowledge in a way that also engages them. By presenting questions to students and getting them to answer (or not), educators can get a better sense of what the student needs help with by determining misconceptions and gaps in knowledge.

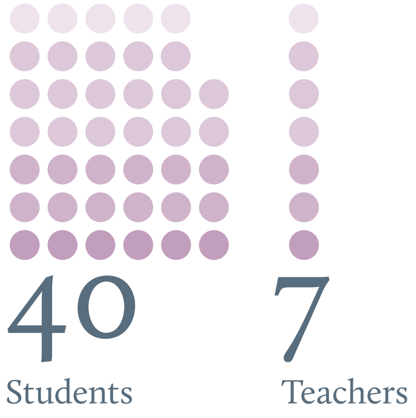
Search

Socratic Questioning can be thought of as a method of search. Tying back to scope, searching for an answer through Socratic Questioning often helps frame the problem. Using the method helps students get started with a search–they have a better idea of what to look for if they continue to ask questions. Furthermore, constantly asking questions during the search process continues to guide the student to make sure that the search path leads to answers for a specific problem.

Summer Design

Upon establishing Socratic Questioning as a design direction with SRI, our team of four completed further research to fully understand the space.

Speaking with teachers and students again helped inspire and validate our design ideas. With less than three months to conduct focused research and design a compelling application, it was paramount for our team to use rapid contextual design techniques in which we grounded design decisions in data, user feedback, and tasks, and rapidly iterated on design ideas. These methods, described here, and the results from our summer research are further detailed in the process section of this report.



Focused Research

To reveal ideas more specific to Socratic Questioning and how it works in the classroom, we asked teachers about how they use the technique and students about how their process of answering complex questions.

Speed Dating

After generating low-fidelity sketches of our initial ideas, we presented them to teachers and students to receive general feedback on pedagogical value as well as perceived engagement level.

Participatory Design

By directly involving biology students in the design process, we generated novel ideas. Getting participants to act out scenarios helped to ground brainstorming activities in behaviors typical to biology students.

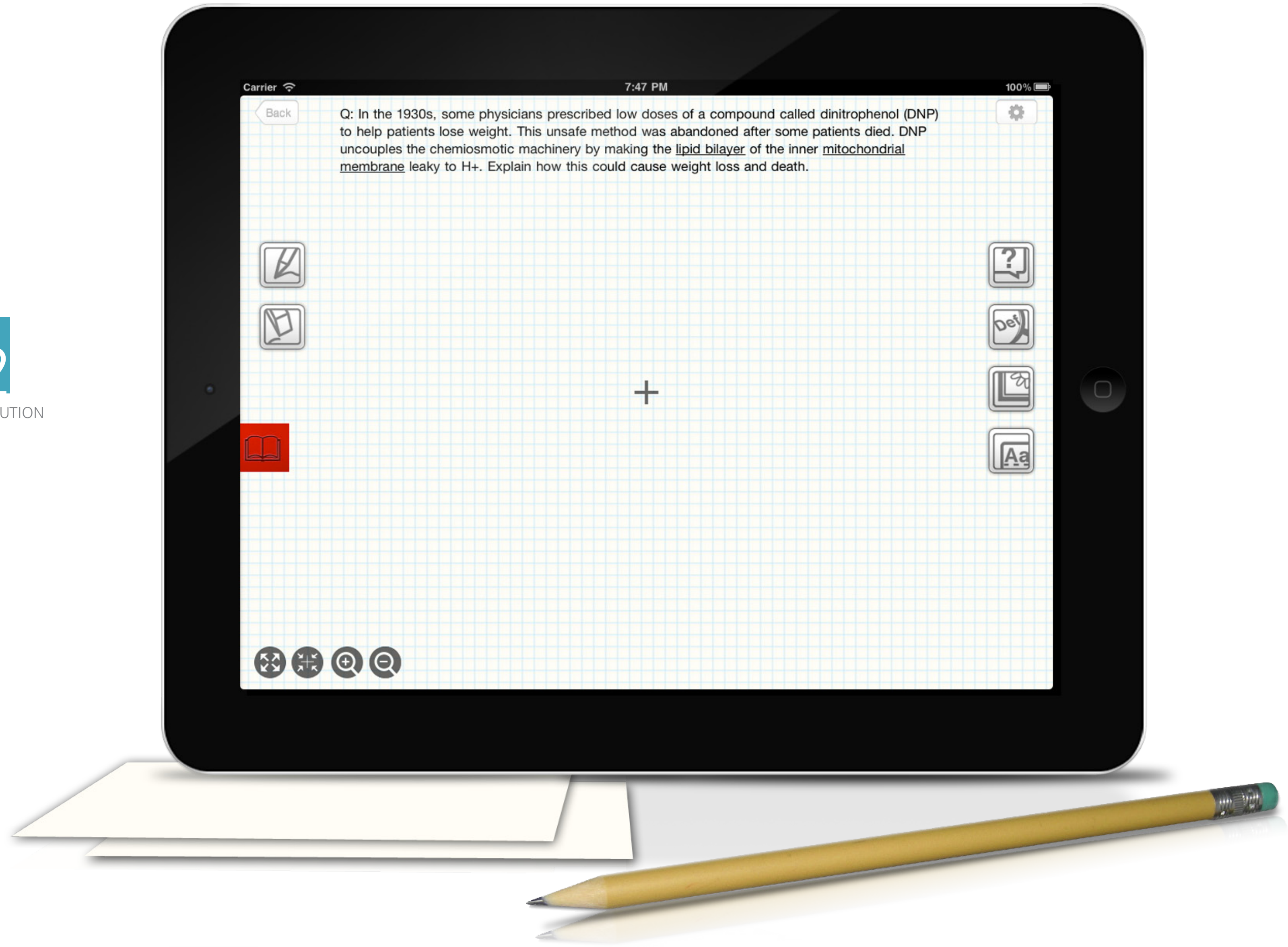
Rapid Iteration

Our process for design began with a high number of low-fidelity prototypes. As we narrowed these down to ideas that teachers and students consistently validated, we moved to higher fidelities. This allowed us to rapidly iterate without wasting time on unworthy ideas.

Design Solution

In the spirit of Socratic Questioning, we explored several ideas that addressed the process of helping students break down complex problems into smaller steps.

The design ultimately evolved to a tool that allows the student to easily approach the work in a piecewise manner, as well as being able to show his or her understanding to the teacher in a meaningful way.



What is Thinkspace?

Thinkspace uses the metaphor of a physical workspace that enables students to quickly consolidate and synthesize information to solve complex biology questions.

Thinkspace takes care of the busy work of having to locate and rewrite relevant information, which allows the student to focus on forming relationships between the bits of information and extract the a solution. To do this, Thinkspace provides the student with several tools such as Ask a Question, Define a Term, Add a Picture, a slide-in textbook, and more. While using these tools, snippets of information are added to the workspace in the form of note cards. These cards can be manipulated and organized in any manner the student sees fit.

With these tools, Thinkspace also addresses the three cross-cutting themes from our spring research: scope, feedback and assessment, and search.

Search

Students struggle to find correct information outside of the textbook to study for exams and complete homework. Information must then be validated before consolidating into notes. Thinkspace provides the student with valid information and provides a convenient space for students to manage this information in one place, removing the issue of syncing.

Scope

Our spring research revealed that finding information at the appropriate scope was often a challenge when looking for material outside of the textbook. Content would either contain too much detail or not enough. Thinkspace counters this issue by providing content from the knowledge base that was built on material from the textbook and subject matter experts. Students can also condense cards to show only the content that they need.

Feedback and Assessment

We also found that feedback and assessment are important to both teachers and students in progressing the learning process. Teachers give students feedback to confirm or correct responses while student response helps teachers understand what students need help on. In the same manner, formal assessment gives both teachers and students quantified measurements of learning progress. While the current version of Thinkspace cannot assess a student's work, it provides feedback based on what the student has added to the thinkspace. The suggested questions and terms constantly updates as the student works and provides new questions and paths of inquiry to follow.

Scenario

John is a high school student taking AP Biology.

He is a fairly hard working student who keeps up with homework and performs above average on tests. Right now, he's applying to colleges and at the same time studying consistently for the AP Biology exam. He knows a high score will make him a more competitive candidate for the colleges he's applying for. Nearing the end of the course, John has begun to prepare for the AP exam in May.

As a weekly exercise to prepare for the AP exam, his biology teacher assigns a focus question for the class. The question this week is taken from the review section of chapter 9. It reads: *In the 1930's, some physicians prescribed low doses of a compound called dinitrophenol (DNP) to help patients lose weight. This unsafe method was abandoned after some patients died. DNP uncouples the chemiosmotic machinery by making the lipid bilayer of the inner mitochondrial membrane leaky to H+. Explain how this could cause weight loss and death.*

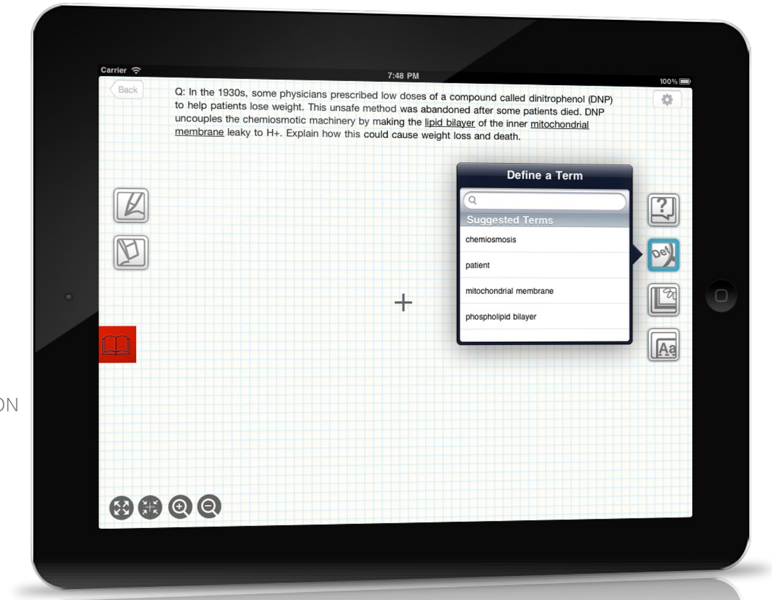
Having become familiar with using Thinkspace for previous focus questions, John decides to utilize Thinkspace again for this week's question.

1 John enters the Thinkspace gallery and starts a new Thinkspace by tapping on the "+" button.

2 He inputs the question to begin. Next, the new Thinkspace is created.

Define chemiosmosis and get suggestions

As John reads the question again, he vaguely remembers that chemiosmosis is a part of cellular respiration, which was a key concept of the chapter. He thinks the phrase *chemiosmotic machinery* might be related to this. So, he uses the definition tool to verify.



1 Tapping on the definition tool icon brings up an option to manually search for a term or define one of the suggested terms.

Chemiosmosis appears as the first suggested term, which he taps on to define.

2 This drops onto the canvas a selected notecard defining chemiosmosis. As well, the selected card displays suggested questions:

What does chemiosmosis cause?
Chemiosmosis is a step of what process?
What undergoes chemiosmosis?

3 John wants to know the answer to the first question, so he pulls it out to create a question card with the answer: *Chemiosmosis leads to synthesis of ATP,* which he knows is the main energy source to maintain life.

4 He knows that ATP is a big concept, so he adds this to the canvas. He has now established a definition of chemiosmosis and that it leads to synthesis of ATP.

Define hydrogen ion gradient

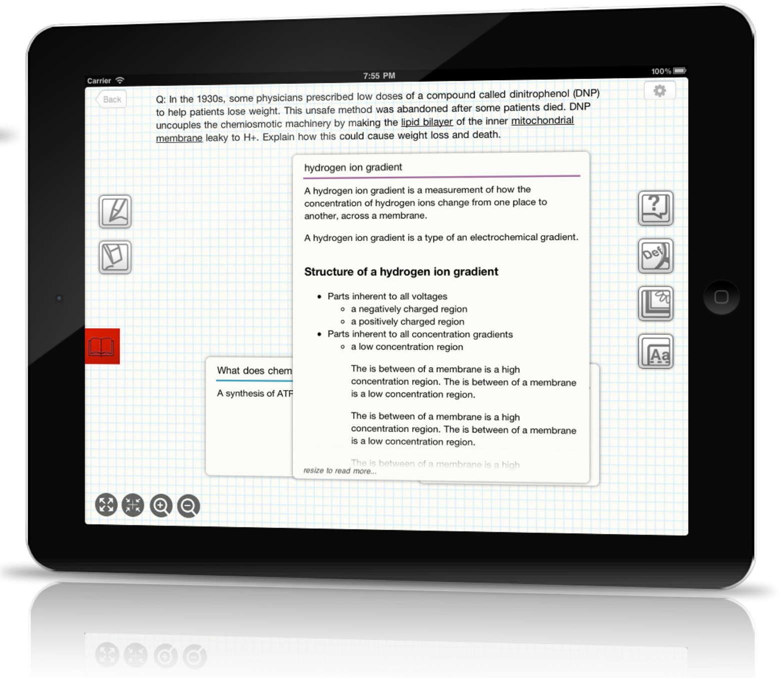
John sees *hydrogen ion gradient* in the definition of chemiosmosis and thinks this could be related to H+ in the question. He uses the definition tool to define hydrogen ion gradient.

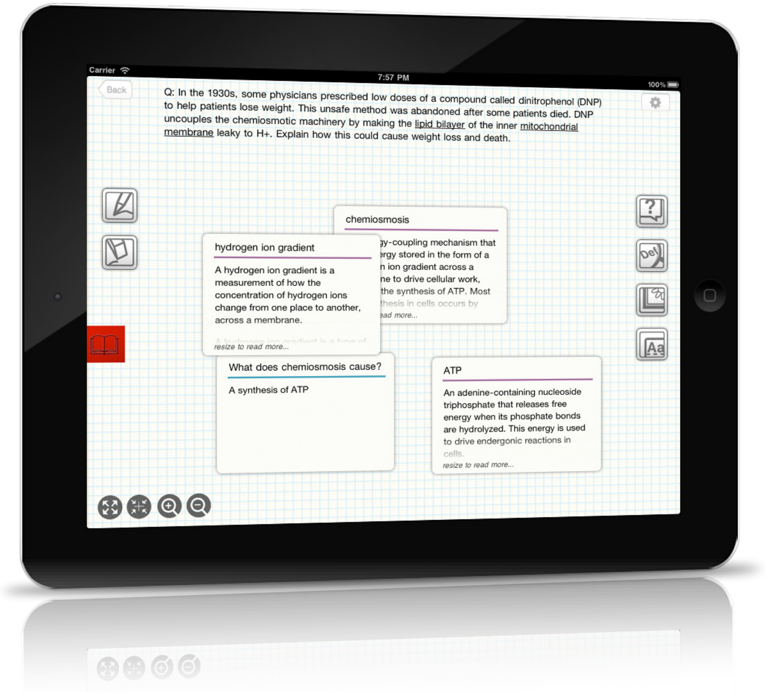
1 The phrase is not suggested, so he looks it up and adds it to the canvas.

2 Since reading the basic definition of hydrogen ion gradient does not lead him to any clues, John resizes the card for more details.

He notices under *Parts inherent to all concentration gradients* two points of interest: both *a low concentration region* and *high concentration region*.

Expanding each point even further, he learns that a biomembrane is between each region.



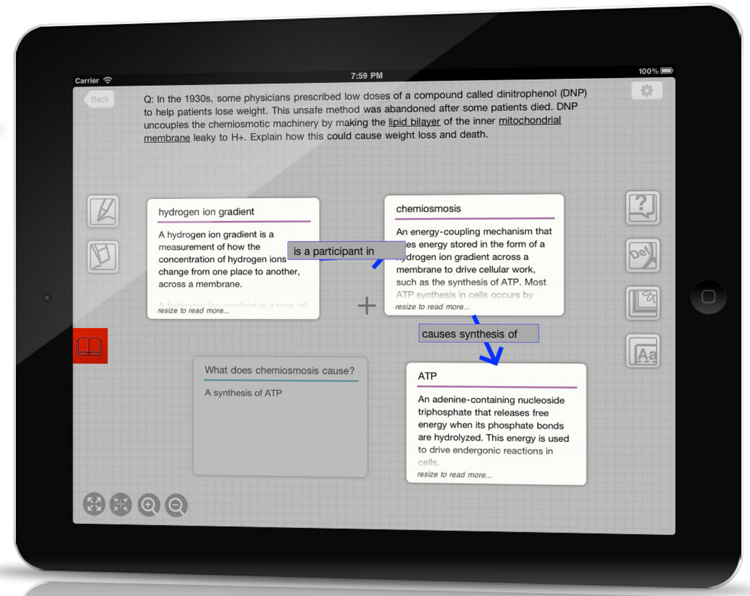


3 At this point, John has established a definition of chemiosmosis, an answer to *What does chemiosmosis cause?* and a definition of hydrogen ion gradient. From the information on the canvas, he has also established that a hydrogen ion gradient participates in chemiosmosis, which leads to the synthesis of ATP.

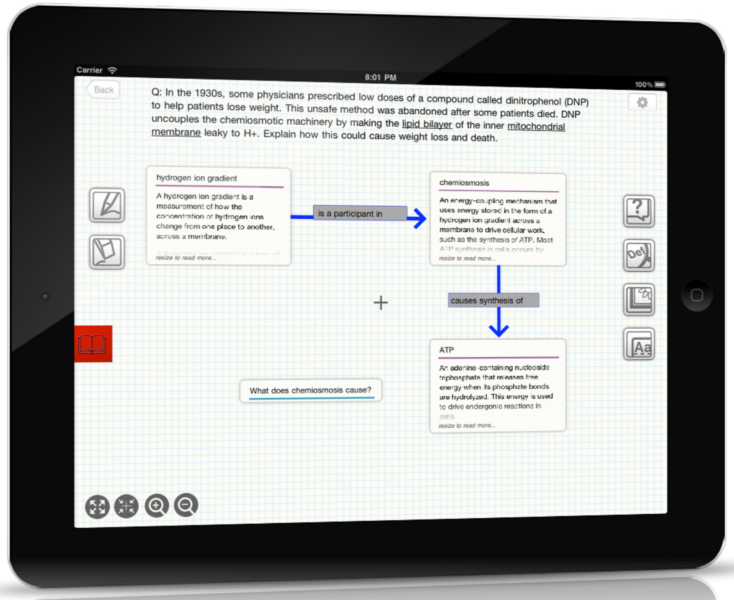
Draw relationship

In order to better visualize how these parts connect, John establishes relationships on the canvas.

1. Tapping and holding on the cards chemiosmosis and ATP reveals a relationship between the two. It reads *chemiosmosis causes synthesis of ATP.*



2. Tapping and holding on the cards *chemiosmosis* and *hydrogen ion gradient* reveals a relationship between the two. It reads *hydrogen ion gradient is a participant in chemiosmosis.*



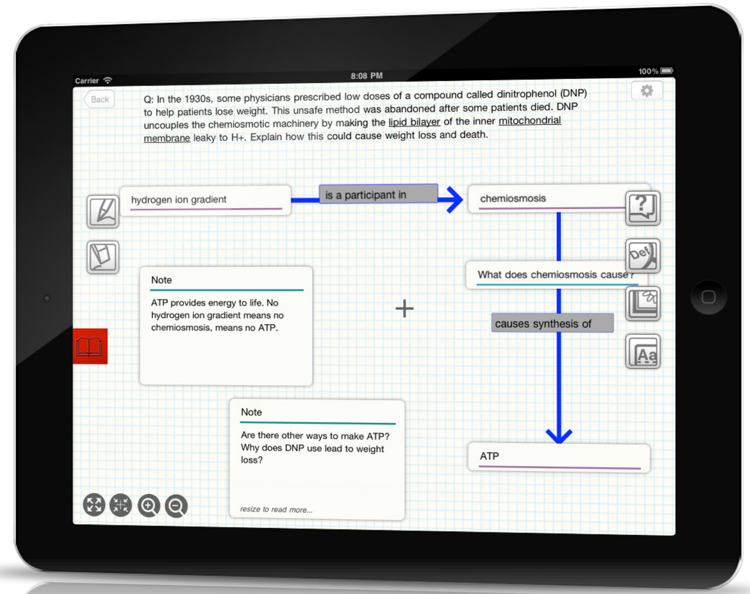
3. John rearranges these cards in a way that makes sense for him. In a sequential left to right arrangement, he creates a flow chart: hydrogen ion gradient -> Chemiosmosis -> Synthesis of ATP.

Now that the concepts and relationships have helped him concretely establish this sequence, John looks at the question again.

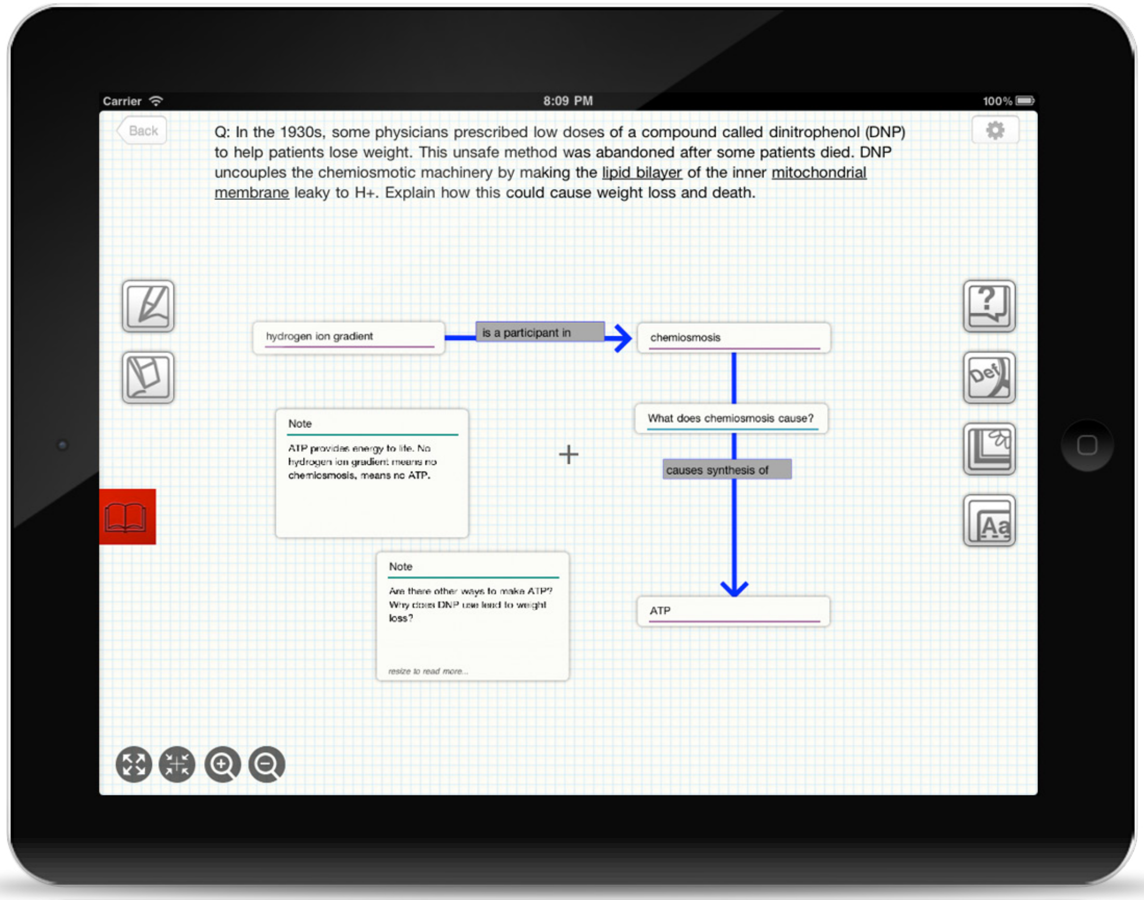
Add an answer

Upon rereading the question, John realizes that a leaky membrane means that a gradient will not be established. Without a gradient, chemiosmosis will not occur and will not synthesize ATP, the energy required to maintain life.

1 He creates a note to add his answer: *ATP provides energy to life. No hydrogen ion gradient means no chemiosmosis, means no ATP.*



2 He thinks about this for a bit and adds *Are there other ways to make ATP? Why does DNP use lead to weight loss?* ending his focus question task for the week and creating further opportunities for him to learn.

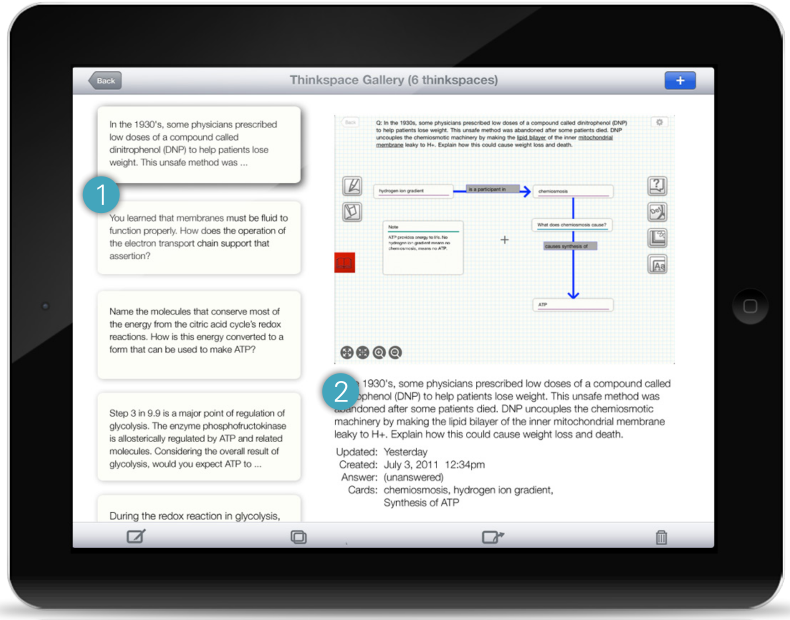


The previous scenario demonstrated a student's use of Thinkspace to help him complete his focus question for the week. The next few pages detail how to create a Thinkspace and the key features of Thinkspace and specific interactions.

Creating a Thinkspace

To start a Thinkspace, open the app to display a gallery of every Thinkspace the student has created to-date.

Creating a Thinkspace is easy. Thinkspace opens to a gallery displaying all of the Thinkspaces the student has created. From the gallery, the student can open an existing Thinkspace or start a new Thinkspace with a question of their own or preloaded from the textbook.



Gallery

Here, the student has the ability to access and edit a previously saved Thinkspace, duplicate one, send one over e-mail, or delete one.

1. In this column, each focus question signifies a single Thinkspace.
2. When a focus question is selected, a preview displays with more detailed information about the Thinkspace.
3. Press the "+" button to start a new Thinkspace by typing in your own question or choosing a question from the textbook.

Note: The Gallery has not been implemented in the prototype. This page presents the entry points into a Thinkspace canvas. To view detailed specs for this page, please visit the UI Specs in the Appendix.

Text and figures from:
Biology (9th Edition) by Neil A. Campbell and Jane B. Reece.

Key Features

The Textbook

The 9th Edition of the AP Biology Campbell textbook can be dragged into Thinkspace for quick reference by tapping and sliding the red textbook bookmark. Users can pull text or pictures from the textbook and add it to the canvas for later use[1]. Research from the last phase and user tests from this phase indicate this as a much needed feature as most students rely on the textbook when studying or doing their homework.

"I definitely like the fact that you can just pull the book out, that's really useful."
– Rodger, College Freshman

The Canvas

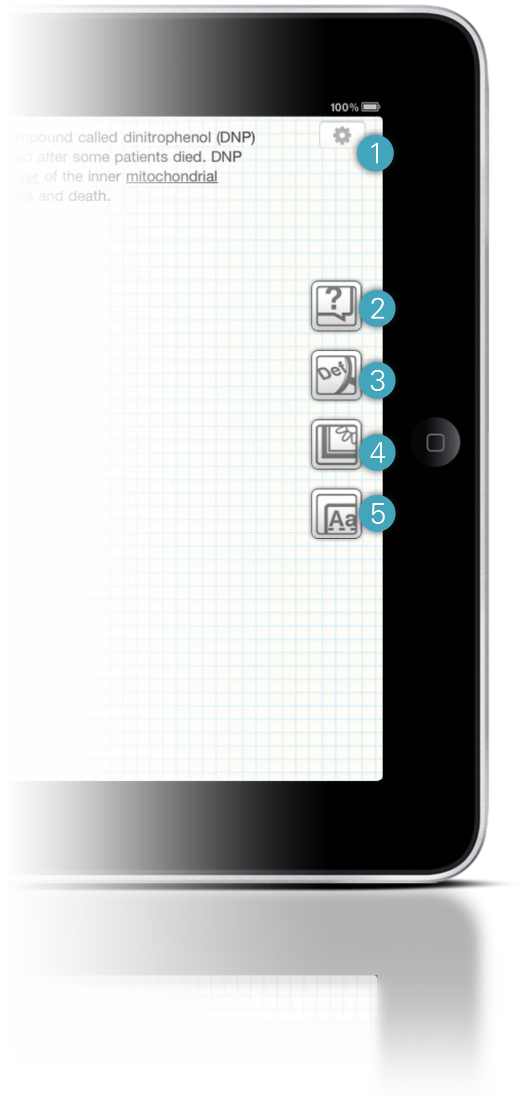
The canvas is designed to look like graph paper to give the impression that the space is casual and editable. The canvas expands infinitely in every direction, can be moved around, and is zoomable for easier navigation and card organization. Because of space constraints on screens of this size, we incorporated zoom and panning to relieve such limits.

"I think you should be able to manipulate your notes the way you want to."
– Amy, College Ph.D

The Cards

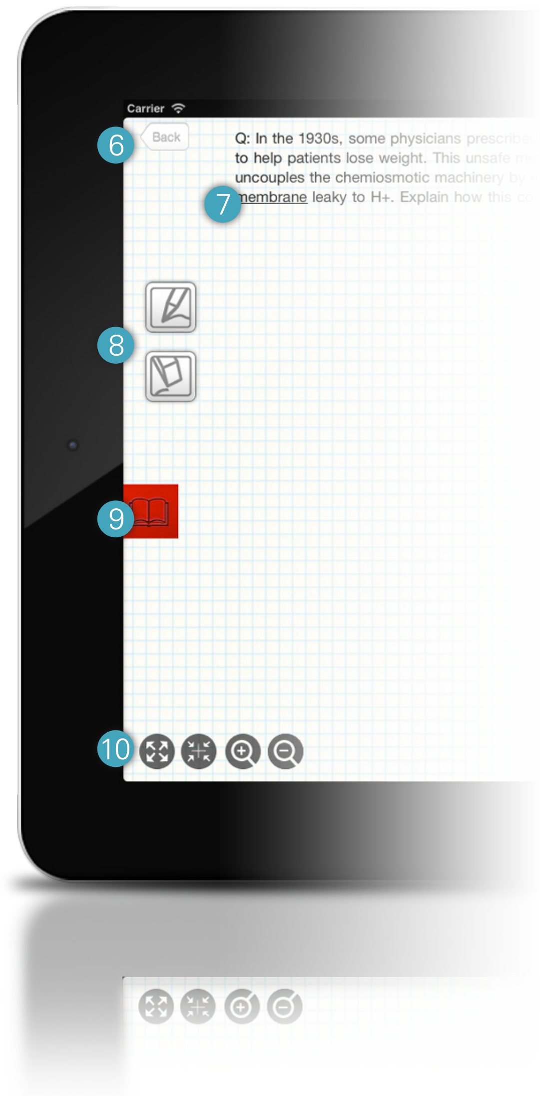
Information in Thinkspace is added in the form of an index card with the title at the top and main content in the body. These cards can be moved, resized, condensed, and deleted as needed. Because each student has their own way of maintaining notes, we enabled cards to allow students to organize information in any way they wish.

1 For the purposes of this project, clipping from the textbook is not implemented in the prototype. Based on user research, we still highly suggest this feature for Thinkspace. UI specs for this feature as well as every other feature can be found in the UI Specs portion of the Appendix.



Features in Detail

1. The **Settings** button allows students to customize their experience.
2. The **Question Asking** tool allows students to utilize Inquire's question asking capability. Much like the QA functionality in Inquire, the student can either input a question to ask or use the suggested questions based on content in the focus question.
3. The **Definition** tool allows students to define specific terms. These may be manually inputted by the student or selected from a list of suggested terms based on content in the focus question.
4. The **Images** tool pulls relevant images from the textbook to help students visualize the concepts on the canvas.
5. The **Notes** tool is a simple way for students to add their own text to a blank notecard. This becomes useful when the student wants to add ideas not present in the knowledge base.
6. The **Back** button at the top left returns to the Gallery, which contains a list of all the questions asked.
7. The **Focus Question** is constantly in view to emphasize the goal of answering it. Especially for long, complex questions, students often glance back at the question to check for content and to verify if they are getting closer to an answer.
8. **Pen and Eraser** tools provide a straightforward way to annotate a Thinkspace. This lets students further personalize their Thinkspace by making notes just like they do on paper.
9. The **Textbook** can be pulled out to reveal textbook content. When a more comprehensive explanation is needed, students can easily peek back and forth between the textbook and the Thinkspace.
10. **Zoom** buttons allow for zooming in closer to see more detail in a Thinkspace or zooming out to get an overview of all the ideas on the canvas.

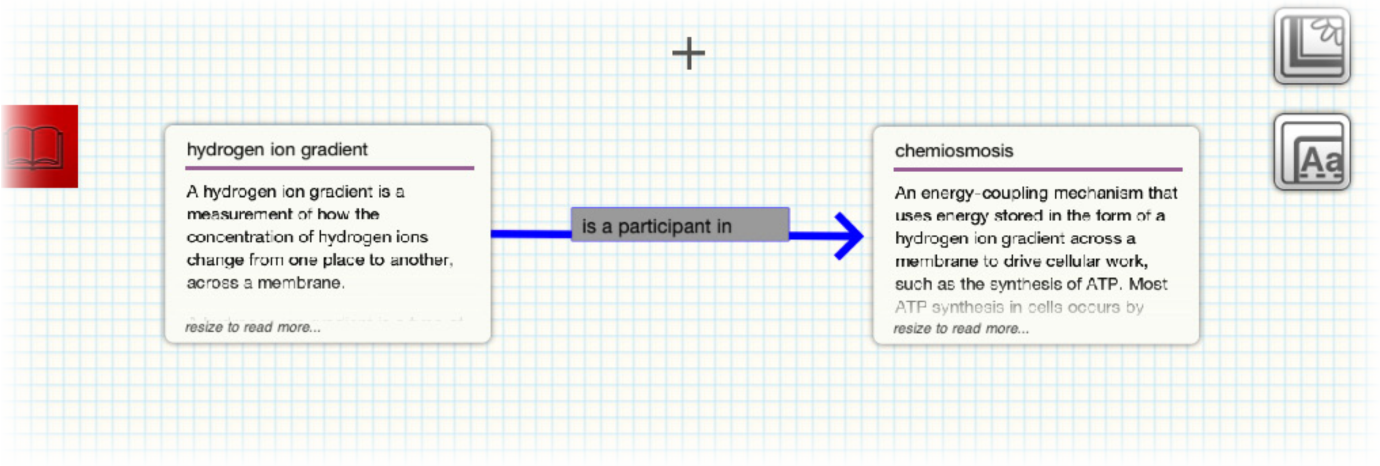


Integrated Workflow Features

The key features described previously bring together several types of content into one space. These tools make it easy to search and browse related content, especially when the student knows what they want to add to the Thinkspace. In addition to knowing what concepts are relevant, students also need support in identifying key relationships in order to answer complex questions. To help students build on their current understanding of biology concepts, we included three additional features in Thinkspace. The features were created to provide extra suggestions and jumping off points that are closely tied to the content on specific cards.

Relationships

The hard part in solving biology questions is tying all of the individual concepts together to form an answer. That's why we built in a feature that reveals the relationship between two cards to help students visualize connections and reach a higher level of synthesis. To reveal relationships, a student taps and holds on a single card, then on a second card to create a text layover detailing the relationship. To permanently add this relationship to the canvas, the student taps a third finger onto the canvas. When the student lets go, all the arrows are removed except for the set relationships.



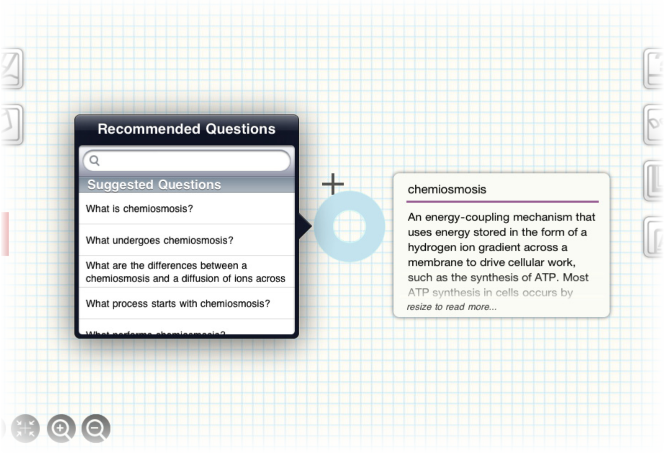
Relationship Tool

Proximity Touch

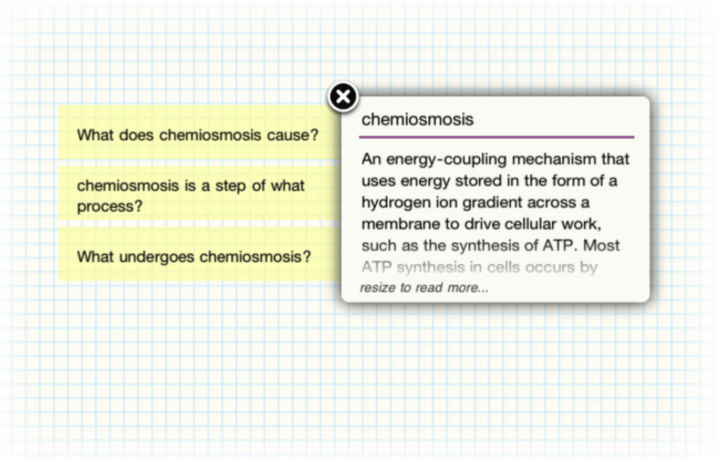
This feature provides an exploratory mode that reveals a menu of suggested content based on nearby cards. To bring up the menu, the student can press and hold anywhere on the screen to bring up a popover menu filled with recommended questions. These questions are generated based on the content of the cards near the student's touch point. As the student moves their finger around the canvas, the popover updates itself to reflect the cards nearby. If a student sees a question they would like to explore further, they can tap on the question in the popover, which creates a new card on the canvas with the answer.

Card Specific Suggestions

This feature prompts students with recommended questions for a particular card to provide further relevant avenues of exploration. When a card is created or selected, the card rises and a few questions on collapsed cards peek from under the selected card. These recommended questions act as jumping off points from this specific card to help develop a line of inquiry to follow to solve the question. A student can drag one of these peeking cards out from under the selected card to form a regular card with its expanded content.



Proximity Touch



Card Specific Suggesitons

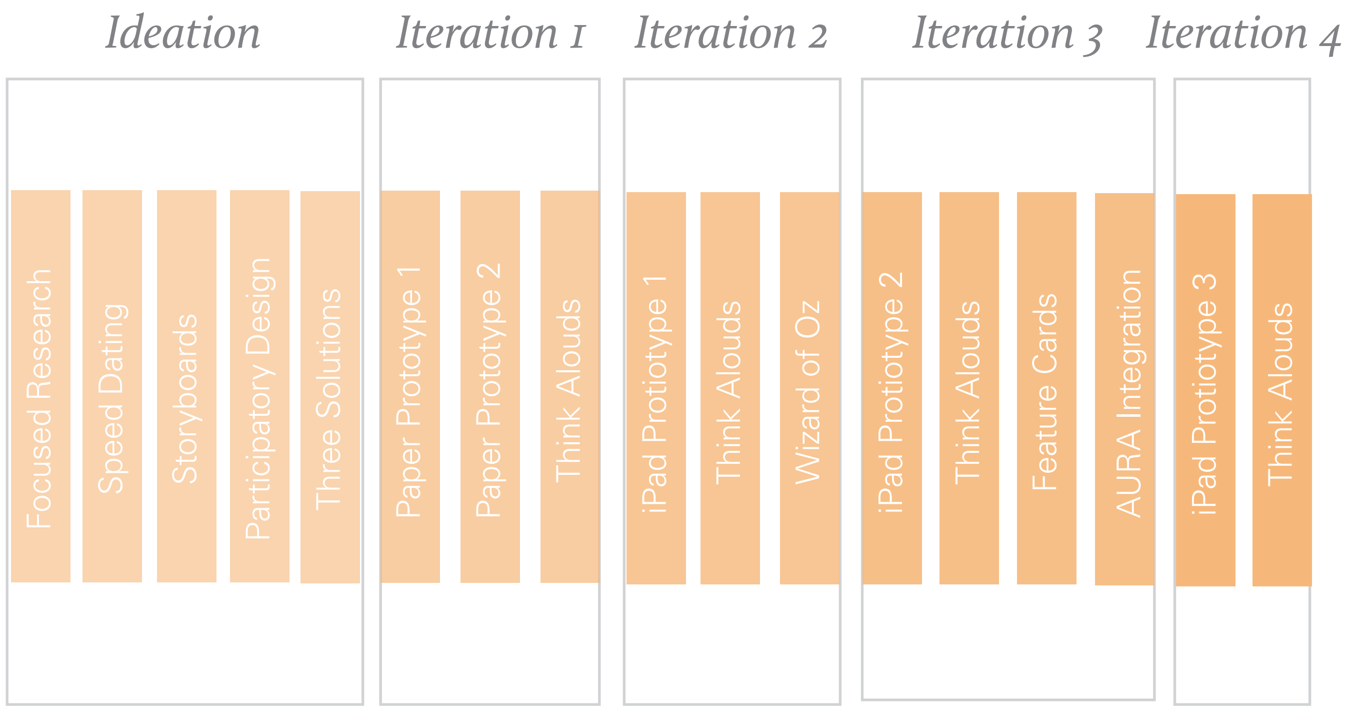
Process

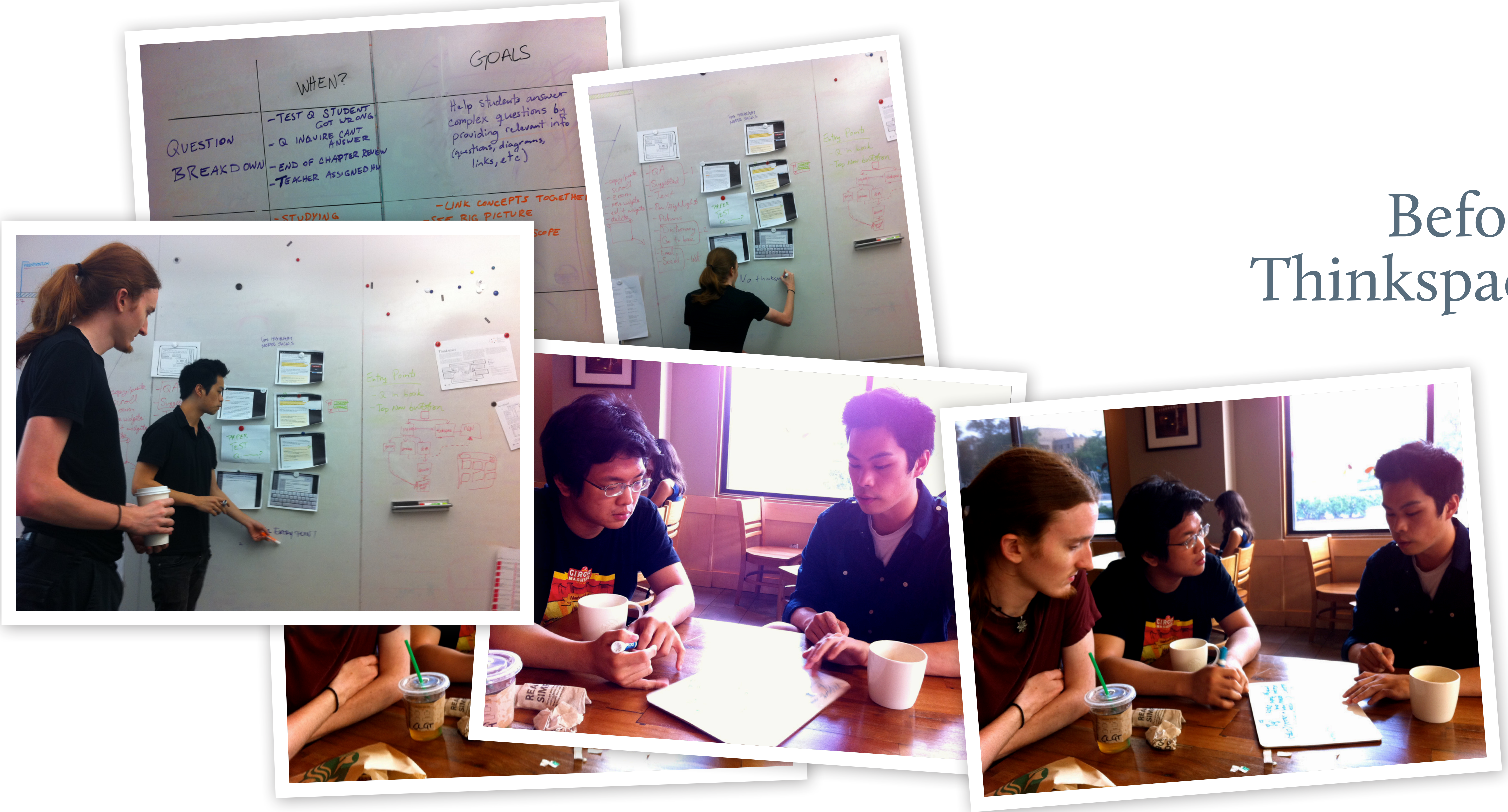
To arrive at our design solution, we took the data we collected from the Spring Semester and started work to design a prototype that would meet the needs of biology students and teachers with the goal of enhancing engagement and facilitating learning.

Process Overview

In this phase, we focused on ideation, design, development, and usability testing.

In the ideation phase, we spoke to users to gain more in-depth knowledge of how Socratic Questioning works in the classroom and rapidly brainstormed several ideas. After generating several ideas, we began an iterative process of design, development, and testing to first advise which idea would be best to pursue and later to refine our chosen idea. In the end, we have produced a designed, developed, and tested prototype that effectively increases student engagement, is easy-to-use, and is teacher-approved. The following pages will walk you through each test we performed, why we chose this test, and the results.





Before Thinkspace

In this iteration, our goal was to create as many ideas as possible, get feedback on these ideas from teachers and students, and finally choose an idea to move forward with and develop thoroughly.

What We Did

We used a variety of methods to help our team brainstorm and then later narrow down our ideas. We first started this iteration with additional research into Socratic Questioning and why it is used. Then we generated several ideas and used Speed Dating, Storyboards, and Participatory Design to vet these ideas with students and teachers.

What We Learned

At the end of this iteration, we settled on three possible solutions to move forward with: Socratic Breakdown, Visual Notetaking, and Concept Map Navigator. We presented these ideas to SRI and after discussing these ideas, we created a new solution: Thinkspace, which integrated principles from each of the three original solutions.

Focused Research

After our visioning session with SRI in May 2011, SRI and Team Halo decided that Team Halo would focus on creating a solution that implemented the principles of Socratic Questioning.

In our research during the spring semester, we had observed how teachers use Socratic Questioning in the classroom to explain complex biology concepts. By prompting students to think through a series of questions, teachers teach students the critical thinking strategies necessary in solving hard problems. Our team wanted to explore this technique further to understand exactly when this method was used and how both teachers and students felt about it. So for the first two weeks of the summer, we set out to speak to teachers and students to gain more in-depth knowledge of Socratic Questioning.

What We Did

We interviewed two high school teachers, two high school students, and one college student to get more information on the use of Socratic Questioning in the classroom.

What We Learned from Teachers

While we knew that Socratic Questioning is used to guide students to answer their own questions, we discovered in our interviews that teachers also use it as a form of assessment on the students. They ask questions to help guide the student and to pinpoint any gaps in knowledge or misconceptions the student may have on the subject matter. Teachers also scope the questions to concepts relevant to the curriculum and to lessons that have already been taught to students in the classroom.

Insights

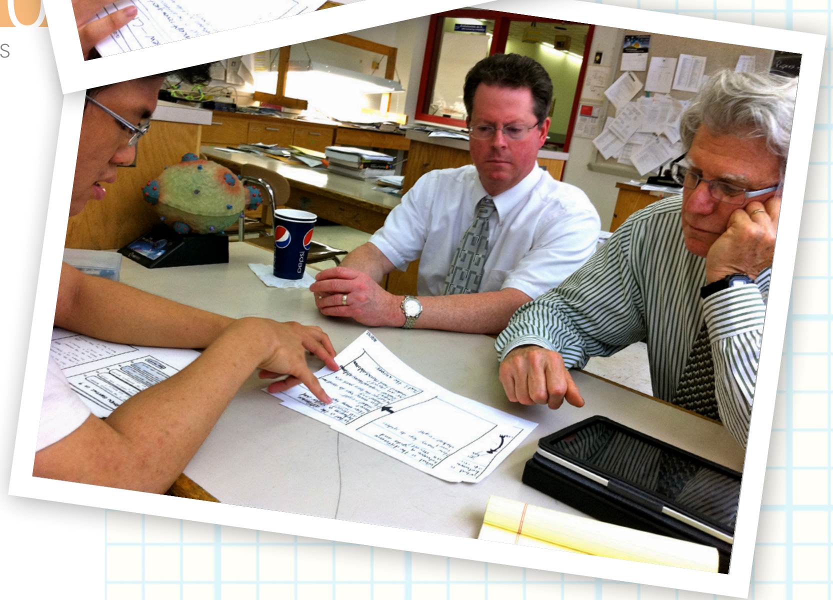
1. The solution we create does not have to focus on helping students answer difficult questions; it could instead use Socratic Questioning to pinpoint gaps in student knowledge and present information accordingly.
2. To use Socratic Questioning effectively, the solution must have information on what the student does and does not already know.

What We Learned from Students

While teachers favor this method, students sometimes do not. Students argue that Socratic Questioning is a long and tedious process to get an answer that does not always work. They understand that Socratic Questioning is being used to guide them along the way, but they get lost during the line of questioning. Teachers know the steps in logic necessary to explaining a concept, but students are often confused and frustrated because they cannot concretely see where a line of reasoning will lead. Students also say they want answers instantly. While Socratic Questioning may help them gain a deeper understanding of the concept, students do not always think that deeper understanding is needed. Oftentimes, a shallow and superficial understanding of the concept is sufficient to pass a test or do their homework.

Insights

1. Students want and need clear visibility of where Socratic Questioning is taking them.
2. Socratic Questioning shouldn't be used in all situations or forced on students.



Speed Dating

Speed Dating in design is a method used to quickly validate concepts.

Participants are shown concepts and a discussion is held around the specific needs these concepts address.

Our Goal

The goal is to find the overlap between the observed needs we identified and the needs participants perceive in themselves.

What We Did

After concluding our focused research, we brainstormed several ideas implementing ideas from our interviews. Some of the ideas included creating concept maps, create-your-own tests, a dialog with the student, and more[1]. These ideas were sketched up and shown to two high school teachers.

What We Learned

From this session, we were able to determine which ideas the teachers liked based on pedagogical value. However, while several of the ideas were pedagogically sound, the teachers doubted whether students would use any of the solutions on their own. The teachers did not forsee any of the ideas motivating the students intrinsically.

1 For a full list of ideas, see the Appendix

Storyboards

Based on teachers' responses from the Speed Dating technique, we drew storyboards to elaborate on the favored ideas.

The benefit of storyboards is that it allow participants to view concepts in their context of use.

Our Goal

Our goal was to get feedback on our storyboards to see which ideas resonated best with students and teachers and narrow down our ideas to focus on one for further development.

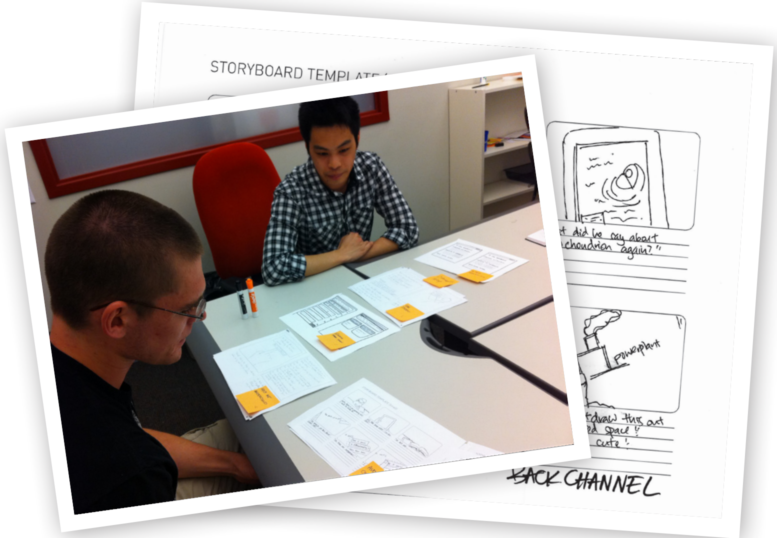
What We Did

After Speed Dating, we fleshed out some of our existing ideas and created new ones. These ideas were then sketched into storyboards to show how and when each of these ideas would come into use. We showed our storyboards to a college freshman in an introductory biology course and a high school teacher teaching honors biology. We asked each person to reflect on each of the storyboards and then to rate the storyboards in order of preference.

1 All of the storyboards can be found in the Appendix.

What We Learned

We got good feedback from the student and the teacher on each idea, but the student and the teacher rated the ideas almost in the exact opposite order. The teacher valued the ideas that promoted more independent thinking while the student preferred the ideas that helped them achieve their goal painlessly. Based on the opposing feedback from the student and teacher, we did not feel comfortable moving forward with any of the ideas in particular. We decided to use a new approach, Participatory Design, to generate ideas more grounded in actual scenarios.



Participatory Design

Participatory Design is a method that involves users in the design process.

We used this method to help brainstorm ideas in the context of a student's work and to make sure we were grounding these ideas in the needs of the students.

Our Goal

Our goal was to generate a solution that satisfied both students and teachers.

What We Did

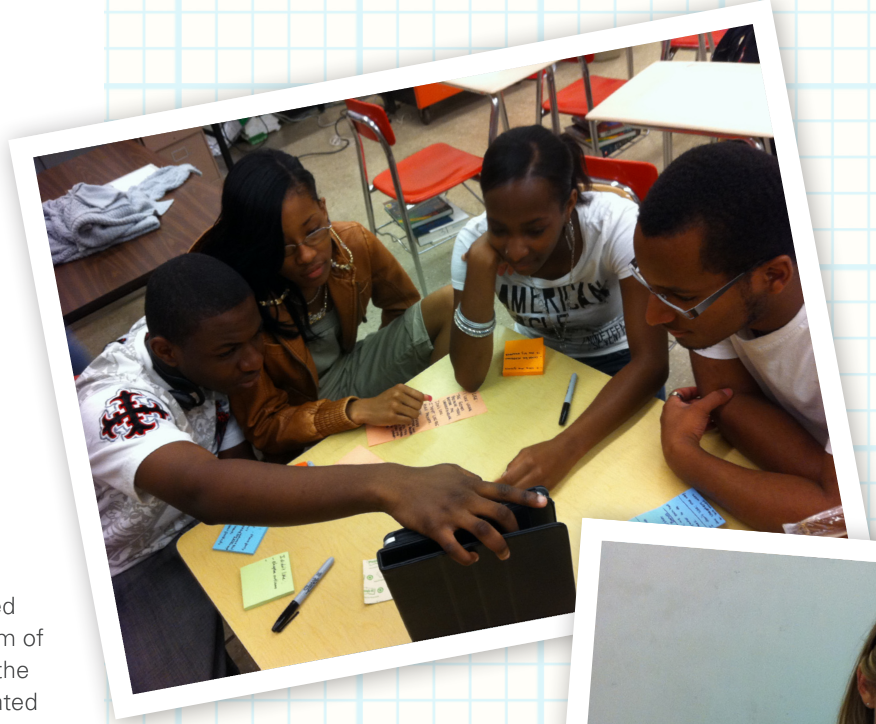
During our design session with students, we asked them to perform three activities:

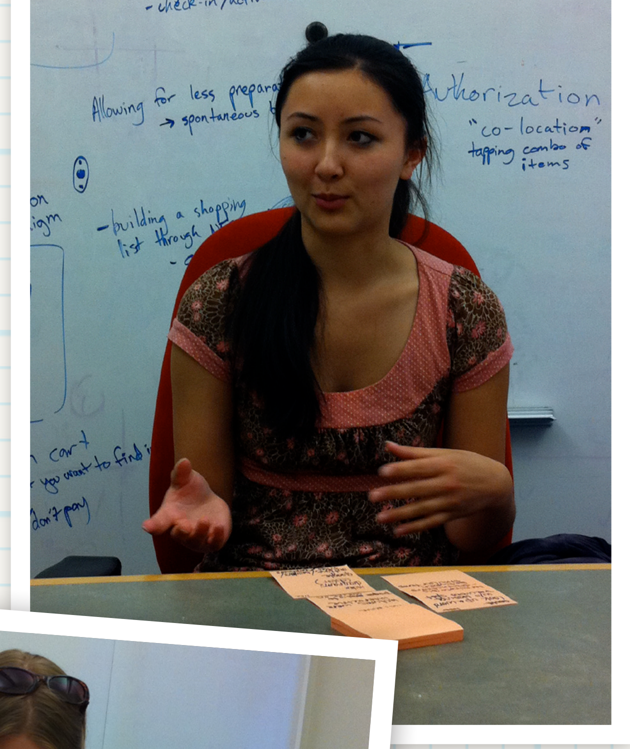
1. I Like, I Wish
2. Bodystorming
3. Thoughts about Socratic Questioning

The first activity asked students to recall the last time they were preparing for a test and to generate Post-it notes detailing what they liked about their process and what they wish was different. In the second activity, we asked participants to pretend they were studying for a test and to bodystorm solutions when we presented breakdowns or dilemmas. The third activity was to get their thoughts on Socratic Questioning and its use in the classroom. We spoke to 18 students.

What We Learned

From these sessions, we collected over 60 Post-its detailing what students liked and wished they had more of. We created an affinity diagram of all of the post-its, grouping similar Post-its into the same category. The other two activities, generated several possible solutions to move forward with. We labeled each of the Post-it groups with one of the generated solutions that addressed the Post-its in the group. In the end, three of the solutions came out on top. We refined these solutions a bit further and came up with Socratic Breakdown, the Visual Notetaker, and the Concept Map Navigator. These solutions are explained further on the next page.





The Three Solutions

All of the work resulted in the following three solutions: Socratic Breakdown, Visual Notetaking, and Concept Map Navigator. Each of these ideas addresses the needs of students and teachers.

Our Goal

Our goal was to show these solutions to students, teachers, and SRI to settle on only one of the ideas to move forward with.

What We Did

We created three concept posters for each of the solutions. These posters are on the following pages. We spoke to four high school AP Biology students, two high school biology teachers, and our clients and discussed merits of each solution.

What We Learned

The students were undecided as to which solution they liked best. The teachers preferred the Socratic Breakdown solution. Our clients liked each of the ideas but felt that a more innovative solution could be created. In the end, we merged each of these ideas and formed Thinkspace.

Socratic Breakdown

Students sometimes have trouble knowing how to answer questions, or where to start figuring out how they answered a question wrong.

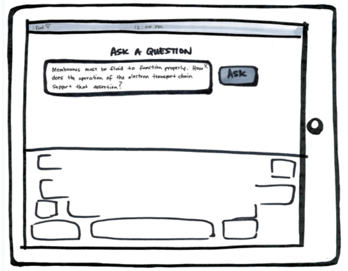
On the other hand, students quickly become annoyed when simply asked follow up questions that they don't know the answer to. This solution enables students to collaborate with the system in breaking down complex synthesis questions into questions that can be answered by glossary pages or Inquire's question answering functionality.

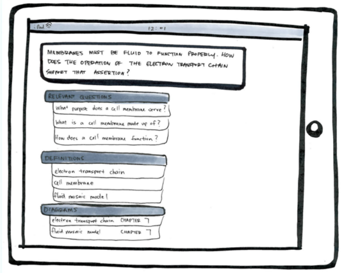
Integration into Thinkspace

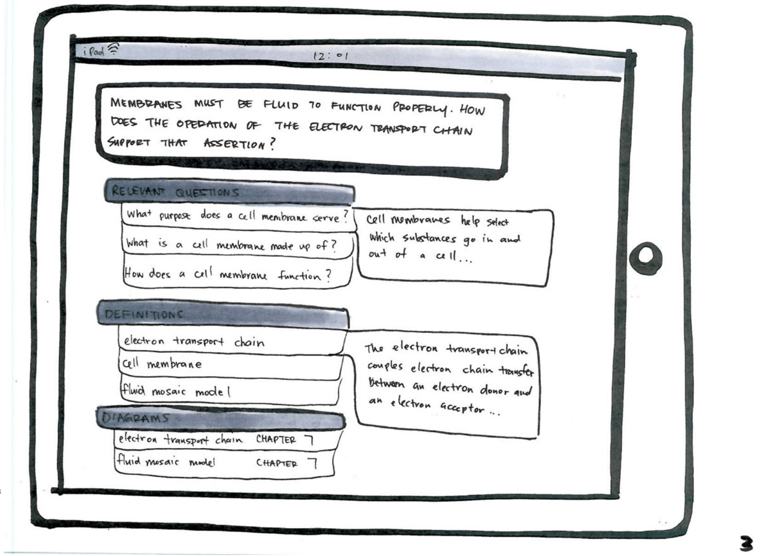
We took the question breakdown part from this solution and incorporated it into Thinkspace in the form of suggested questions.

Key Benefits

1. Help students quickly break down difficult questions into ones that they can begin to tackle.
2. Break down complex questions into concepts or basic questions Inquire can provide information on.
3. Let students survey all the relevant facts so they can keep track of everything they need to answer a complex question.







Visual Notetaking

Based on our research during spring semester, students prefer and learn better using visuals and diagrams.

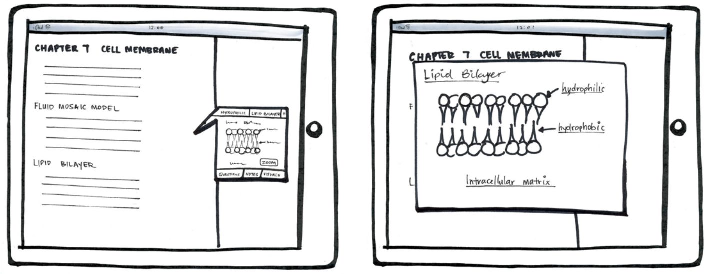
Students also study by creating their own diagrams or using pictures from external sources to guide their learning. Our empirical research shows that students rely on these images to better understand and memorize biology concepts. This solution is a drawing and visual manipulation tool that allows students or teachers to tie diagrams to Knowledge Base concepts.

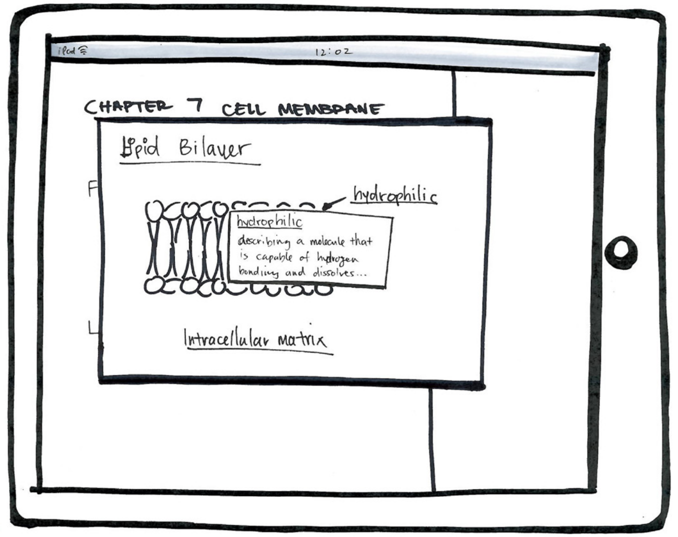
Integration into Thinkspace

In Thinkspace, students are allowed to draw on the canvas and import pictures from anywhere in the book. Concepts in Thinkspace can be manipulated in several ways that facilitate the need to visually represent information.

Key Benefits

1. Allows students to access even more diagrams than the text provides, since biology is highly visual and diagrams frequently contain most of the information.
2. Students frequently remember things by virtue of remembering the pictures associated with them; custom pictures might strengthen this effect.
3. Interleaves supplementary images with Inquire's native materials by attaching new images to the Knowledge Base's concepts.





Concept Map Navigator

When examining the details of cellular biology, students easily forget that some biological processes are a tiny but important part of a much larger process.

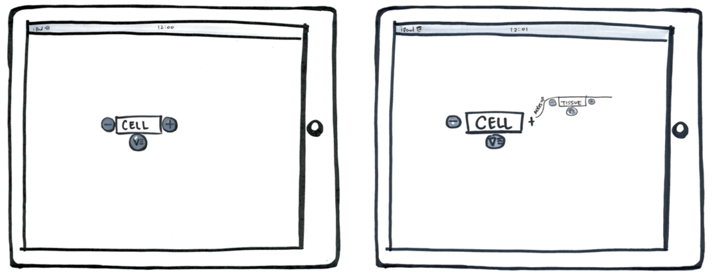
This solution uses a zoomable concept map to show the relationships between different concepts at varying scales. By providing more detailed information about these concepts, students could use this tool both as a summarization of material and to tie together concepts that they're currently learning, in order to see the larger picture.

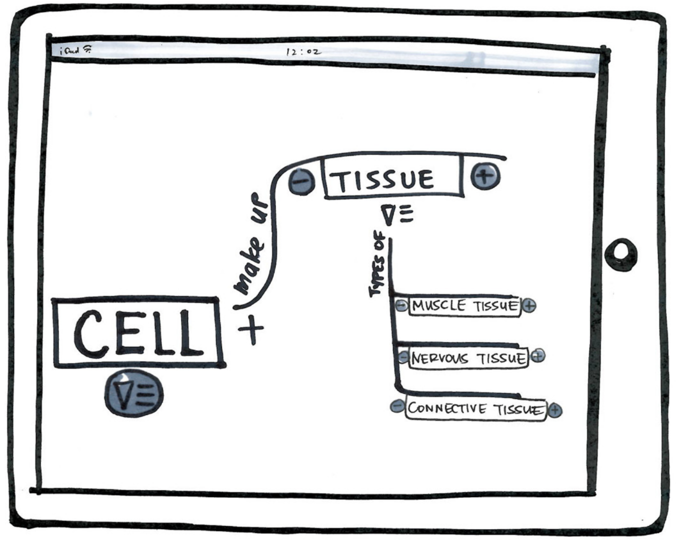
Integration into Thinkspace

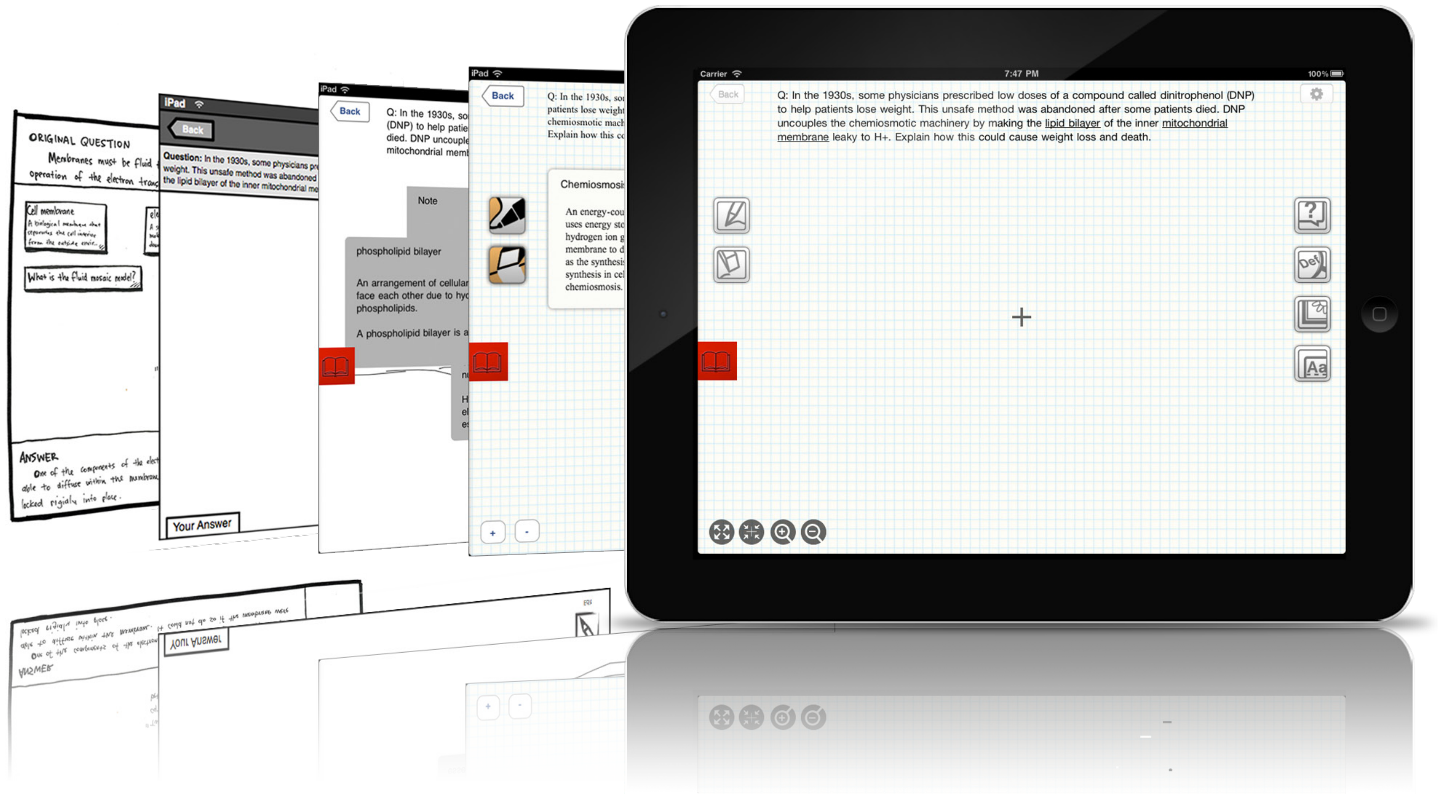
Thinkspace takes the exploratory nature of this solution and manifests it in the integrated workflow features like Proximity Touch. The Relationships feature also allows to students to see how different concepts relate to each other in a bigger picture.

Key Benefits

1. Shows students how concepts relate to other processes at the same scale.
2. Uses zooming to relate concepts, like cellular biology, to larger systems they exist within, like entire organisms.
3. Integrates with existing study processes to maintain awareness of relationships within concepts while studying the details of these concepts.







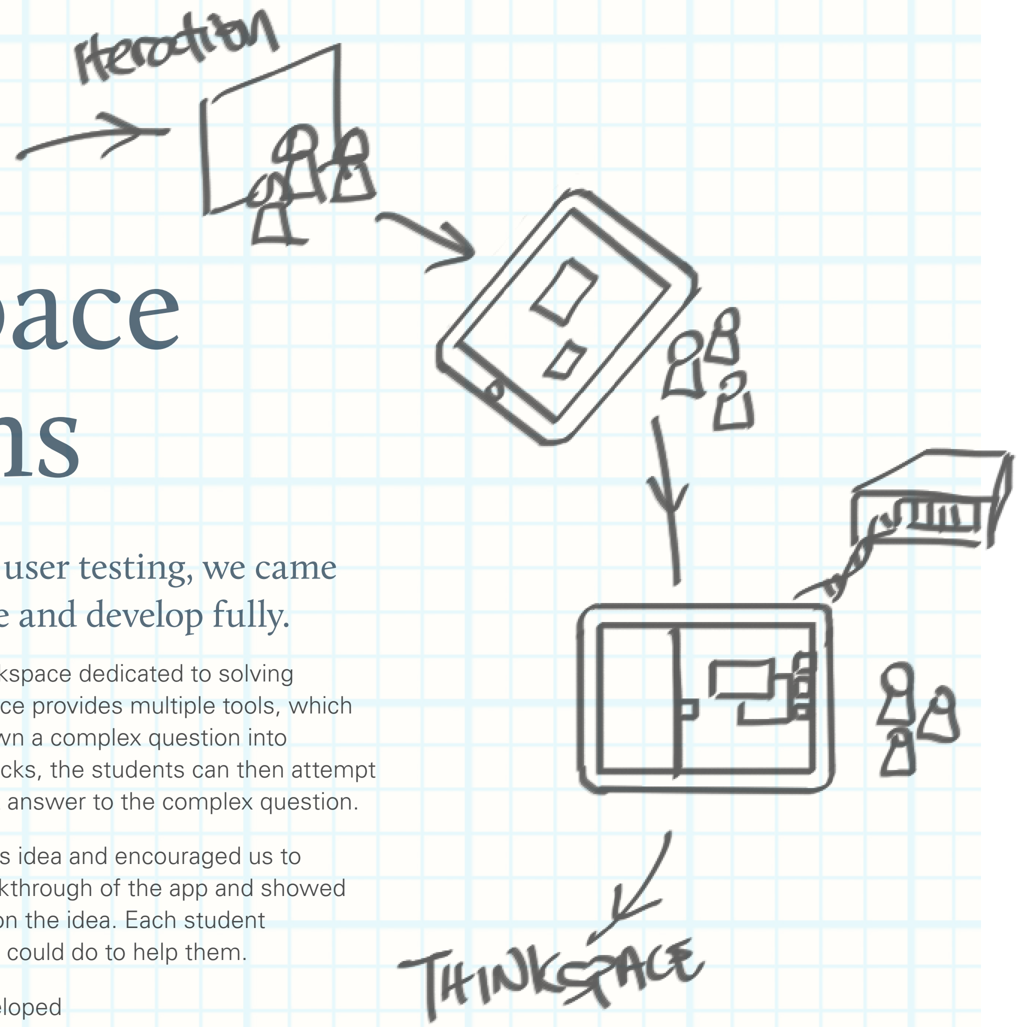
Thinkspace Iterations

After all of the ideation and user testing, we came up with a solution to explore and develop fully.

Thinkspace takes the metaphor of a workspace dedicated to solving complex biology problems. The workspace provides multiple tools, which students can reference to help break down a complex question into manageable parts. Using these basic blocks, the students can then attempt to synthesize these parts into a coherent answer to the complex question.

SRI was pleased with the potential of this idea and encouraged us to explore it further. We created a brief walkthrough of the app and showed it to four students to get their feedback on the idea. Each student was excited about this idea and all that it could do to help them.

The next iterations explore how we developed Thinkspace's features and interactions.



Concept Validation

Our Goal

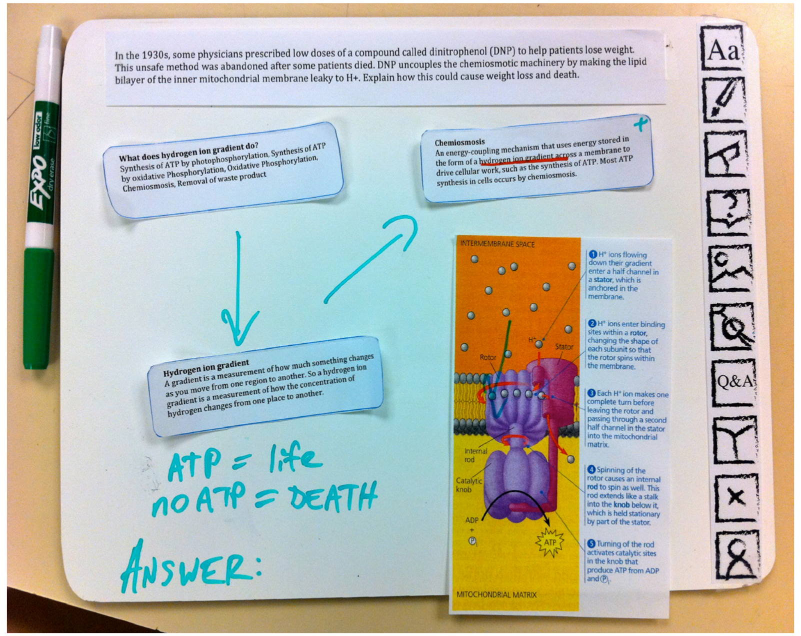
To validate whether teachers, students, and SRI are excited about the idea of Thinkspace and its potential.

What We Did

We sketched up how we initially envisioned Thinkspace along with a short storyboard of its use. We sent these sketches to SRI for their review and feedback. At the same time, we ordered iPad sized whiteboards on which we taped a complex question and paper buttons. We took these whiteboards to four high school students in Advanced Biology and walked them through possible interactions in Thinkspace. After the walkthrough, we asked the students their thoughts on Thinkspace, its interactions, and potential. A whiteboard was used to make the interaction of drawing with a pen more realistic and to quickly draw out any interesting extensions that we thought of on the spot.

What We Learned

SRI approved of the concept and thought it used AURA appropriately in a way that would push the technology and engage students. All four students also approved of Thinkspace. They all commented on the ease to organize the different information on the screen and loved how all of these tools were located in one place. The students also mentioned how they would use Thinkspace for school projects in addition to problem solving.

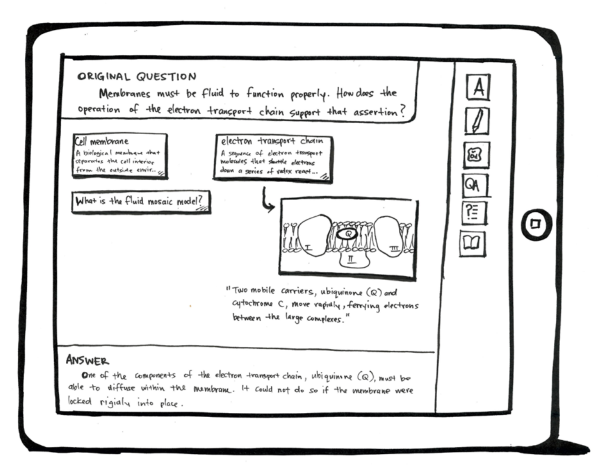


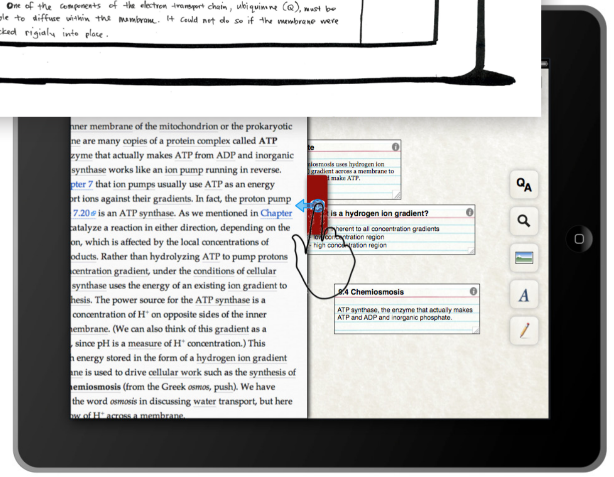
Drawing Activity

As part of concept validation, we created a scenario to demonstrate how Thinkspace could be useful while solving a problem. We quickly created paper cutouts and used marker boards to simulate the Thinkspace canvas. We showed this prototype to four students and walked them through the scenario. We then asked them about their impressions of Thinkspace. Our participants were demonstrably excited about the concept. They liked that it consolidated different kinds of information in one place and could be used for a myriad of other uses in addition to solving complex questions.

Concept Storyboards

We created various mock ups as a way to show our participants and SRI what the final concept of Thinkspace would look like. It also included various simple mock ups of gestures that would potentially be used to interact with Thinkspace.



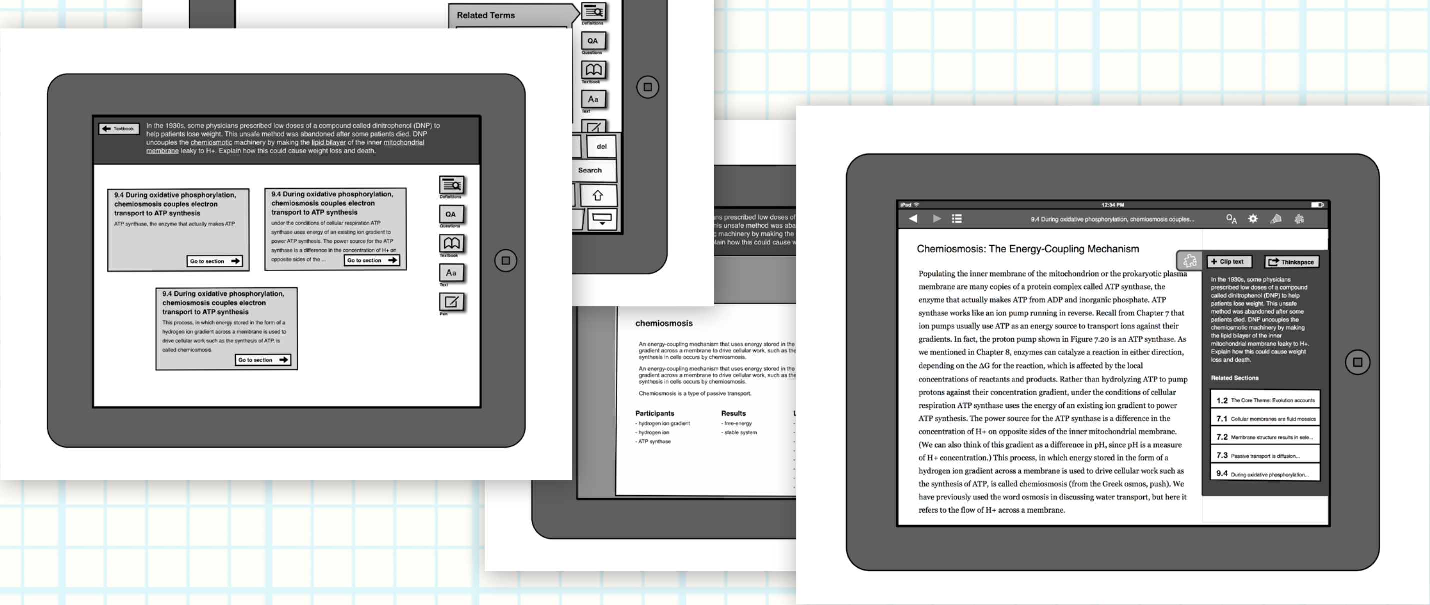


First Iteration

Goal
Upon settling on the concept of Thinkspace, we needed to determine the general workflow and interactions. At this point, it was important to still stay roughly low-fidelity so that no major design details are made.

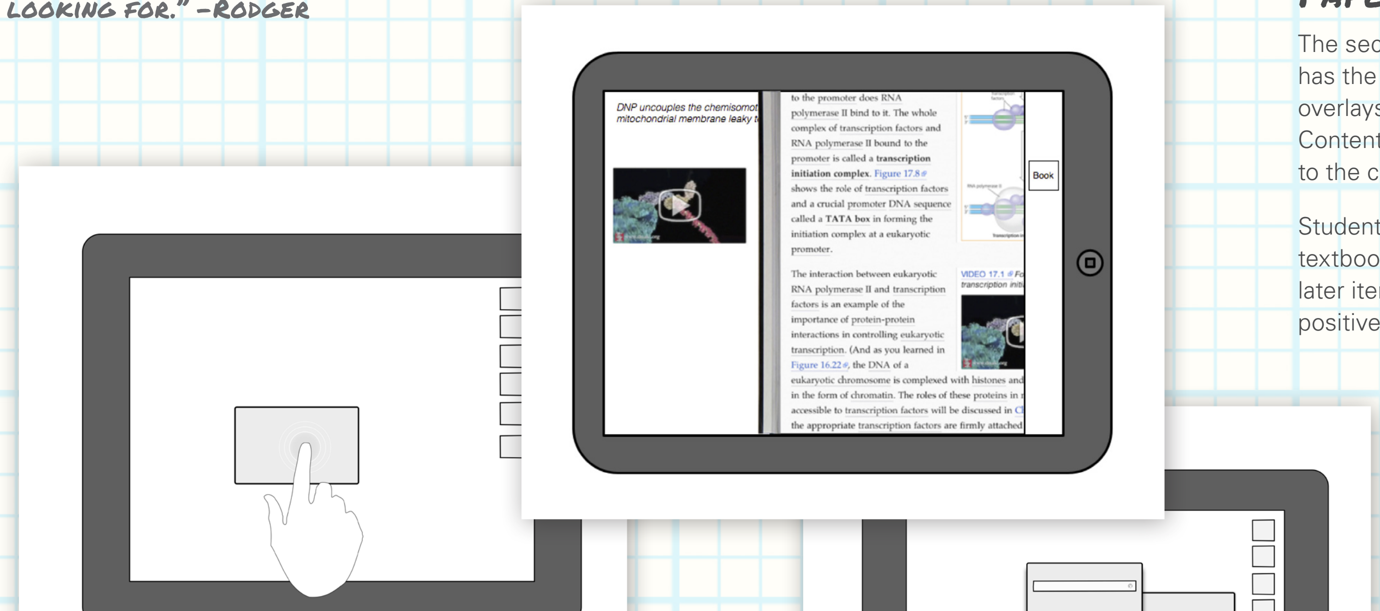
What We Did
We created two separate ways that Thinkspace could be integrated with the current Inquire app. The first acted as nearly separate app from Inquire. Once inside Thinkspace, all of the tools you needed were located right there. There was little need to return to Inquire since both the textbook and question-asking technology were already integrated. The second workflow we created was much more integrated with Inquire. In order to import any information into the Thinkspace, you had to go back to Inquire, use the tools it already provides, and then import those actions into Thinkspace. We created paper prototypes of each workflow and showed it to three biology students. We asked participants to think aloud while performing these tasks to get a sense of what was usable and which features facilitated the student's workflow.

What We Learned
While both workflows received positive reviews from users, actions performed in the separate workflow were more streamlined since they never had to switch screens and everything was in one place. For this reason, we chose to move forward with this idea for the next iteration.



"I DEFINITELY JUST LIKE THE SPEED AND THE AVAILABILITY THAT I CAN BRING IT UP HERE INSTEAD OF FLIPPING THROUGH THE CHAPTER TO FIND WHAT I'M LOOKING FOR." –RODGER

"I WISH I COULD JUST PRESS ON THE WORD IN THE QUESTION AND IT WOULD JUST SHOW ME WHAT IT MEANS." – JULIE



Paper Prototype 1
This first way of integrating the textbook content with Thinkspace takes the user directly to Inquire. To keep a focus on answering the focus question, a menu appears in the right margin displaying the question, relevant sections, an option to clip content from the textbook to add to Thinkspace, and a direct button that returns to the Thinkspace.

Although this method integrates more tightly than the alternative below, it subtracts from Thinkspace the advantage of having textbook content in the same space as Thinkspace content. Our tests with students revealed confusion when trying to clip text to add to a Thinkspace.

Paper Prototype 2
The second workflow that we mocked up actually has the textbook pull over the Thinkspace so that it overlays the canvas, like it does in the current prototype. Content can be clipped from the textbook and dragged to the canvas without ever exiting Thinkspace.

Students understood the metaphor of dragging a textbook on top of Thinkspace's workspace canvas. In later iterations that implement this, we consistently see positive emotional reactions to the textbook slide-out.

Second Iteration

In our next round, we tested the interactions in Thinkspace with a real touch screen rather than with paper prototypes.

Our Goal

After we selected the workflow Thinkspace would follow, we needed to test the interactions of the cards on screen, the textbook slide out, and gestures.

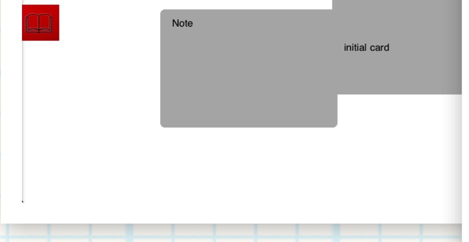
What We Did

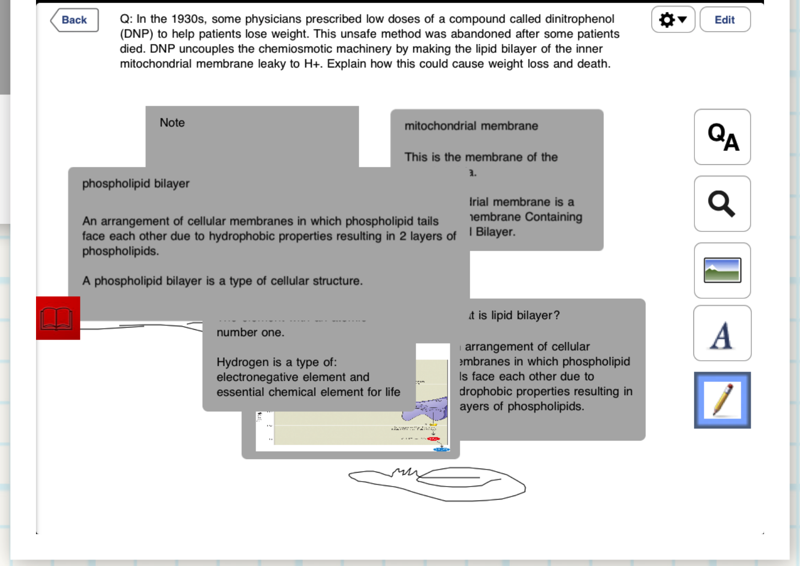
We began to develop a high fidelity prototype in the iPad because it has built-in gesture recognizers, making it more efficient to develop in than HTML. We hard coded biology information into the different features and preloaded the workspace with a question from the book. We then showed Thinkspace to three biology students and asked them to solve the question. We asked users to think aloud during the test and noted when they became frustrated or encountered a breakdown in the interface.

What We Learned

In this iteration we hard coded all of the biology information, which limited the amount of information the students could search through. This caused several roadblocks for students as they solved the problem. We were only able to test the interactions of Thinkspace and not the effectiveness of Thinkspace in helping students solve complex problems. Here are some of the interaction issues we saw:

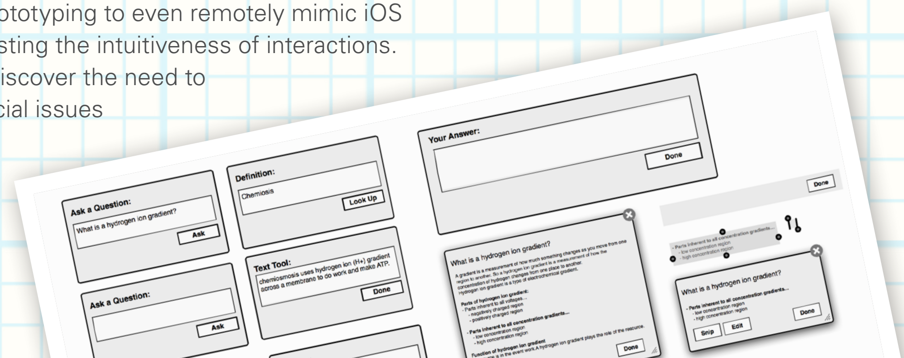
- Unclear how to lower keyboard
- Hard to delete cards
- Hard to resize cards
- Unaware of more information on cards





Why Not Paper Prototypes?

While paper prototyping has proven to be an excellent technique for discovering navigational flow issues in systems that have multiple screens, we found it to be ineffective in testing our concept which focuses on a single screen. This is partly due to the fact that the effectiveness of our idea depends on both the immediacy and quality of content. Without the ability to generate the content on demand, it was difficult to see how effective Thinkspace was in helping students solve a question. As well, the inability of paper prototyping to even remotely mimic iOS gestures inhibits testing the intuitiveness of interactions. We did, however, discover the need to improve on superficial issues like iconography.

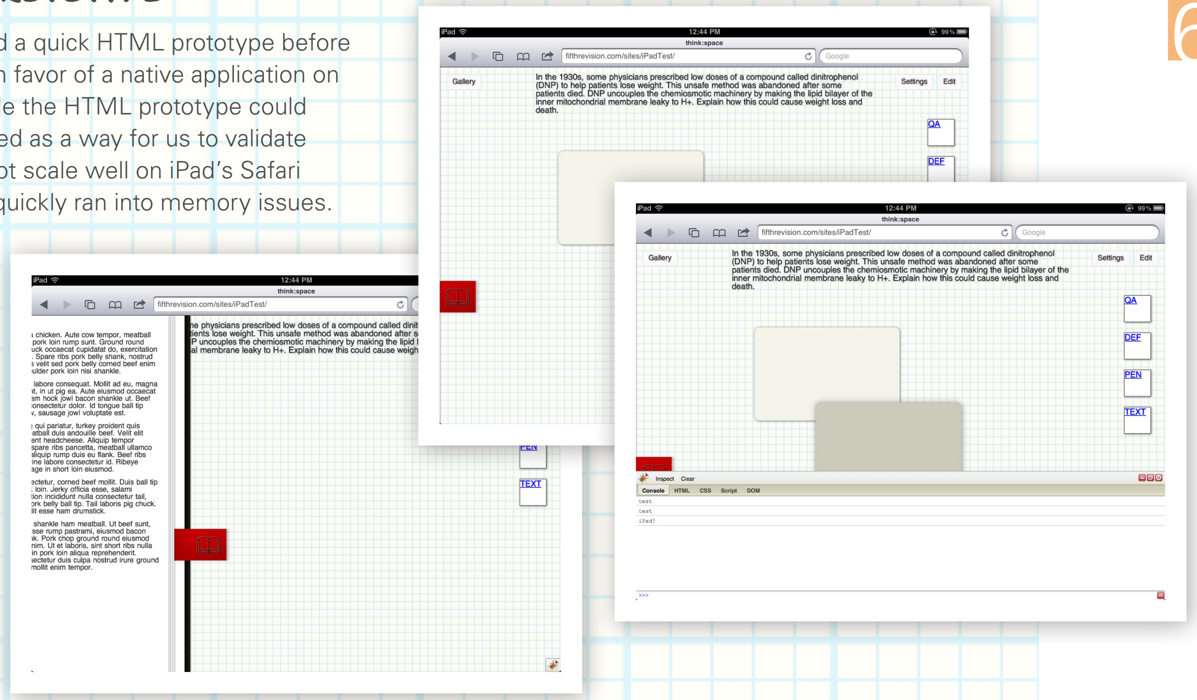


Testing With Users

We developed an iPad application prototype implementing all of the basic functionalities in the Thinkspace design. We used one of the questions present in the Campbell Biology textbook as our test question and created content anticipating the questions that the users might ask while interacting with our system. However, this proved to be insufficient and fell short when put in front of users.

HTML Prototype

We developed a quick HTML prototype before discarding it in favor of a native application on the iPad. While the HTML prototype could have been used as a way for us to validate ideas, it did not scale well on iPad's Safari browser and quickly ran into memory issues.



Third Iteration

From the second iteration, we rapidly iterated and improved on our iPad prototype.

Our Goal

In this round, we wanted to validate whether Thinkspace actually helped students in solving complex problems after hooking it up to AURA. We also wanted to test which features should be added to the Thinkspace that would extend the use of the knowledge base and help students when stuck.

What We Did

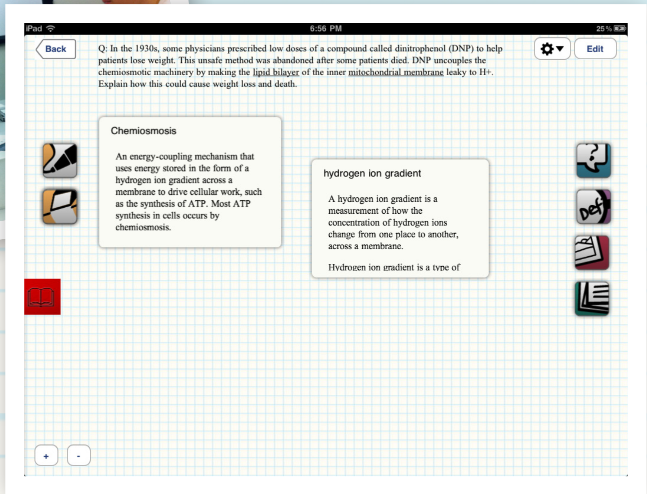
From the results of the user tests with the second Thinkspace prototype, we changed some of the interactions to make it more usable and hooked it up to AURA so that we were populating the app with real data. We also cleaned up the graphics in the app to make it cleaner and more visually appealing. After these changes were made, we tested Thinkspace with four students.

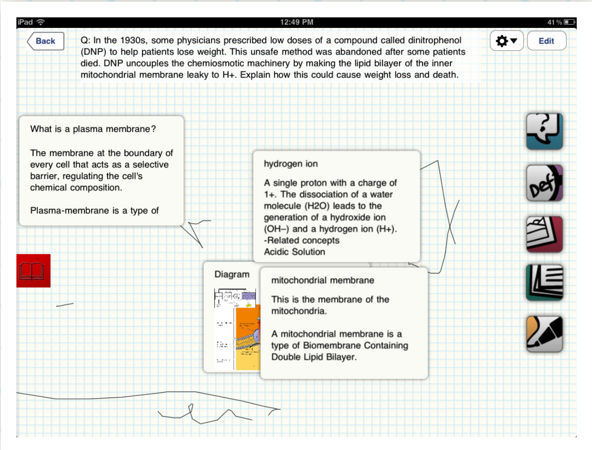
We also created 13 feature cards, each illustrating a possible feature that would help students in the process of using Thinkspace to answer complex questions. These features also utilized the knowledge base and artificial intelligence more explicitly. After performing the think aloud, we asked students to give us their preference on each feature card and their top three favorite features. Features included an avatar that helped you solve the question and having the cards behave like different biological processes like cell division. A list of all of the ideas can be found in the appendix.

What We Learned

The main usability issues we observed were problems manipulating the canvas. All the students we observed encountered problems with zooming and panning the canvas to keep track of their content.

Also, with AURA connected, we had a better opportunity to observe more realistically how Thinkspace could facilitate problem solving. We also began to see students taking the general strategy of defining unknown terms before anything else. Of the students who failed to answer the question despite having started with this strategy, the majority expressed confusion in tying together concepts. The most popular feature cards, described on the next page, address this confusion.





AURA

In order to create a more comprehensive test, we hooked up the prototype to the AURA server to enable real time question asking. This allowed us to create content for the student dynamically, which created a more realistic test.

Visual Improvements

One of the major improvements we did was to clean up the various parts of the design. We paid attention to how elements are represented on screen, such as making sure the canvas metaphor is convincing and subtle cues such as color coding cards according to their types. The result eliminates many of the basic perception usability issues that confused our participants in the earlier iterations.

"This is perfect for them to lay out their ideas." – Mr. Hathy

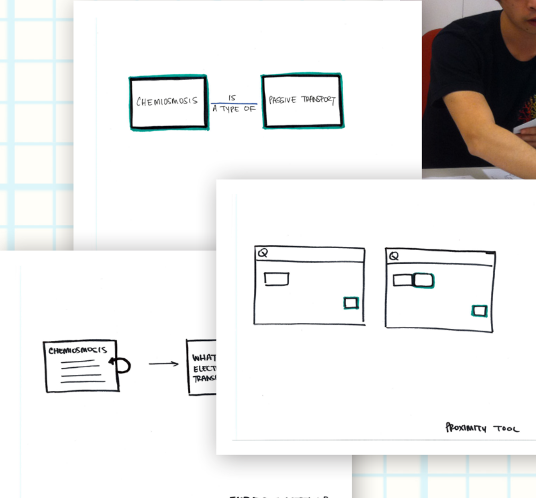
"It's nice to have everything here instead of having three to five web pages open at once, a piece of paper here, and a textbook here." – Amy

Feature Cards

In addition to our base features, we decided to design features that would help students study more effectively. We brainstormed around 13 ideas and created feature cards to concept validate these ideas with our participants. The three most popular ideas were:

1. Auto Relationships: The auto relationship tool suggests possible relationships between cards on the canvas
2. Proximity Cards: The proximity card is a special card that suggests questions regarding other cards in the vicinity.
3. Flip over questions: The flip over question is a concept that allows users to "flip" a card over to reveal similar questions.

Eventually, these feature cards became the basis for the Integrated Workflow Features in our design.



Fourth Iteration

Our Goal

In the final iteration, we aimed to validate the usefulness of the top three features from the previous iteration. As well, we wanted a deeper understanding of how students use Thinkspace when it utilizes AURA to provide more useful content.

What We Did

We continued to make improvements to the existing interface based on student feedback:

- By rearranging the placement of the Pen tool, we distinguished it from the other options that generate cards.
- To deal with space constraints and navigation, we implemented the ability of zooming out to view the entire canvas and also the ability to navigate to the center of the canvas. These options are found at the bottom left of a thinkspace.

To better demonstrate the potential of AURA, we implemented the three most popular features from the last iteration's Feature Cards[1]:

- Auto Relationships was renamed to Relationships
- Proximity tool was renamed to Proximity Touch
- Flip for suggestions was altered to immediately display suggested questions on the side of a card as soon as it is added to the thinkspace. This feature is referred to as Card Specific Suggestions.

We showed this iteration of Thinkspace to five students and asked them to think aloud as they try to solve the question at the top of the screen.

What We Learned

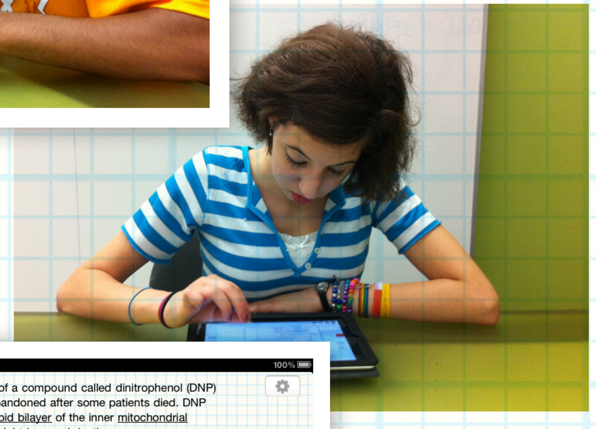
Tighter integration with AURA made Thinkspace a more valuable tool. Of the three students who successfully solved the question, all three had a similar strategy of defining unknown keywords within the question such as *chemiosmosis* and *hydrogen ion gradient.* Once these students understood these concepts, they looked for how the concepts connected.

In addition to having this general strategy, the successful students were able to filter out distractor information, or content in the question that was not relevant. In contrast, the students who failed to answer the question using Thinkspace had focused on irrelevant information in the question.

"This is pretty neat. How long do you think before something like this would actually be available?" – Dr. Rashford

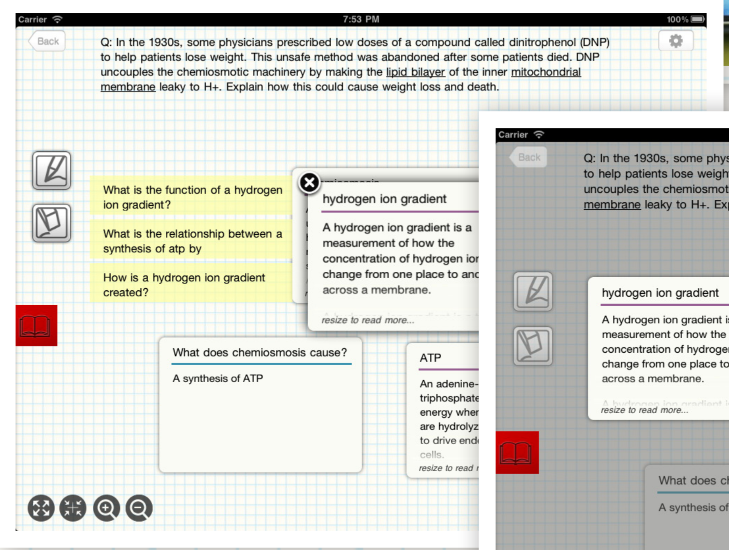
1 These features are renamed and described in the Design Solution section under Integrated Workflow Features.

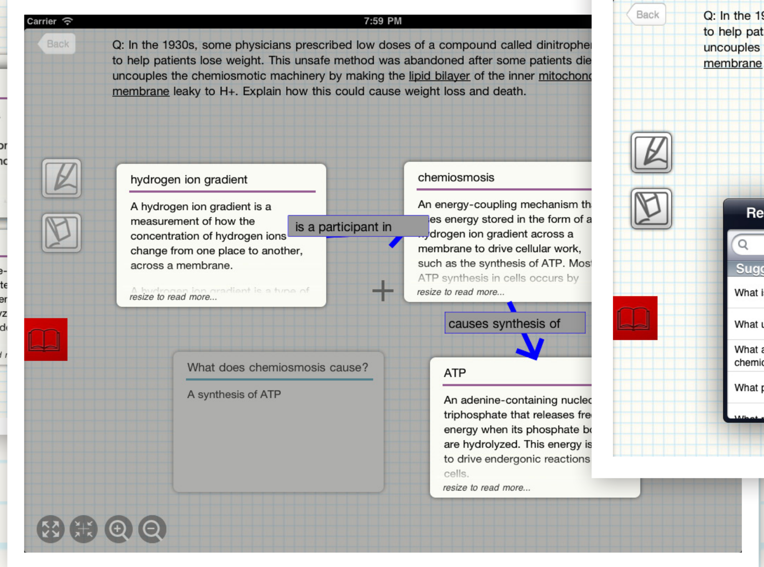
"I got absorbed in it. Once I figured out a pattern, I could go here, get this definition, a question about it, read that question, get another question to walk me through it. It made making connections a little bit easier." – Alexis

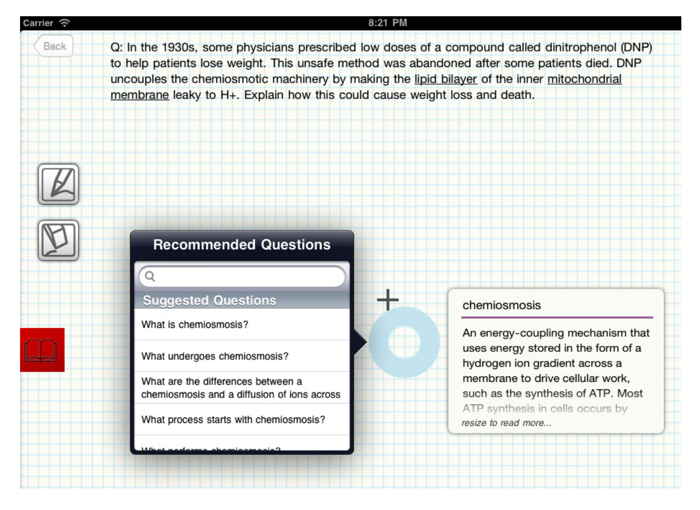


Integrated Workflow

One of the main goals of this iteration is to demonstrate the feasibility of the Integrated Workflow Features that we designed as a result of the features cards tested in the previous iteration. We managed to get all of them working in this final prototype.







Conclusion

In this report we present a design solution addressing the needs of AP-level biology students with a specialized interface to the Halo question-answering technology.

During our spring research, we noticed that students and teachers frequently tackle the challenge of breaking down complex questions. Teachers use Socratic Questioning to help students understand complex concepts while students must figure out how to answer hard questions by breaking them down into smaller steps. Since AURA can not directly answer these questions, and in fact it may not be pedagogically valuable to simply answer them directly, we propose a workspace within which students can follow various lines of inquiry using AURA's help before synthesizing an ultimate solution.

Over the summer

we have refined our solution, leveraging insights from our spring research, discussions with teachers and other experts in the field, and the results of user tests of students solving a complex problem using our prototype.Using these sources of feedback, we rapidly iterated and created a high fidelity prototype which students can use to solve actual problems. This prototype serves as both proof of concept and as a testbed for refining our design.

In addition to this high fidelity prototype, we present a complete UI specification[1], detailing how we envision all the Thinkspace's interactions, including those we did not have time to prototype. We also outline the next steps for taking our vision forward, including a plan for continuing to refine and validate the design.

Our work over the summer has generated a solid foundation for students to build answers to complex questions using SRI's knowledge base and reasoning system. In order for Thinkspace to become the optimal solution, in terms of engagement and pedagogy, further steps must be taken to validate and extend the current prototype.

1 Located in Appendix CD

Next Steps...

Validate

While we have completed initial rounds of validation in the process of refining our design, further research would better validate both the pedagogical value and the engagement level of our solution. The next steps of this project includes direct integration with the current curricula of high school biology classrooms. As well, longitudinal testing would uncover deeper aspects of our solution's pedagogical value. Instead of giving the tool to students to solve a single problem, we would also be interested in seeing how students might use it while following their normal study habits and in the classroom.

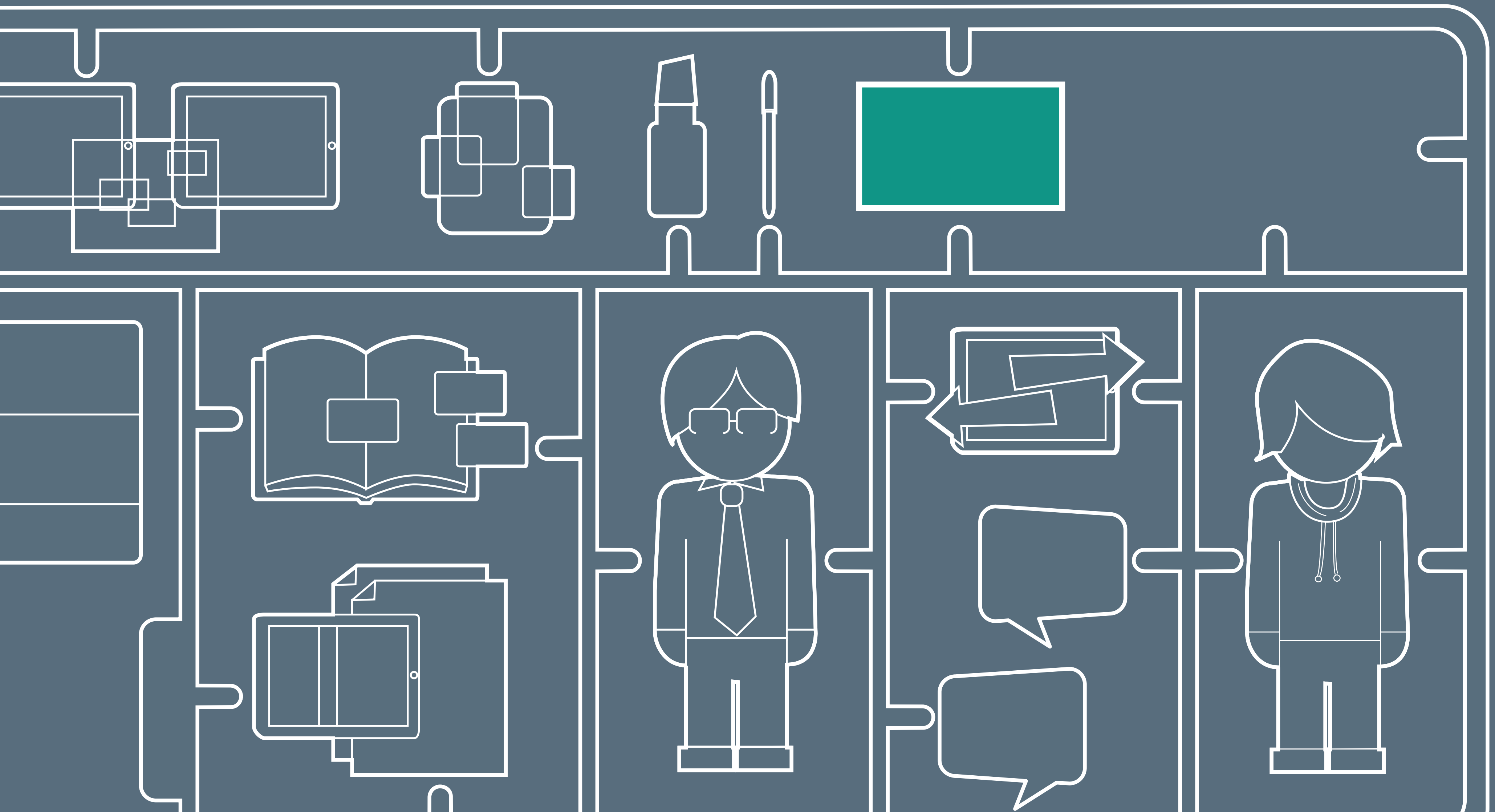
Implement

Future work includes polishing user interactions and the interface. This includes functionality that would allow clipping from the textbook, condensing cards, fully implementing the picture viewer, and fixing known bugs[1]. As well, fully implementing the suggested back-end functionality will make the tool more useful in the real world. This includes things like customizing suggested questions and definitions to give students suggestions that they have not already asked.

Extend

Finally, there are a number of avenues for expanding on Thinkspace to create a tool which would have a more vibrant presence in the learning process. Additional functionality like teacher-student interaction within a Thinkspace or designing Thinkspace such that it can also be used to consolidate information for projects might turn it into a more holistic solution. We expand upon a number of these possibilities, which we did not have the chance to research or design in detail, in the Future Visions section.

1 A full list of bugs and UI Specs for these features are available in the Appendix.



Future Visions

The greatest aspect about Thinkspace is that it provides a solid foundation in which interesting pedagogical work could build upon.

In this section, we detail future visions the team has to extend the capabilities of Thinkspace. We believe these visions would be successful if implemented based on our research in the field and feedback from users. These ideas improve upon various aspects of the software, such as making the base toolkit much more robust as well as adding a meaningful social layer on top of it.

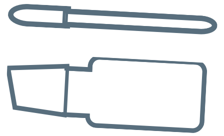
Advancing Thinkspace

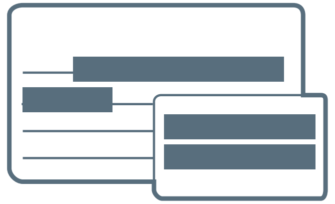
Our design solution provides a solid foundation that encourages and facilitates critical thinking in biology students.

In this section, we list a few ideas to further enhance Thinkspace and its reach. These ideas have not been fully designed or user tested, but based on feedback from previous user tests and observations, we believe these additions would increase Thinkspace's usefulness as well as increase engagement levels and user satisfaction.

Add a Highlighter or Condense Tool

The current Thinkspace has a set of built in tools. From our user studies, we have seen participants wonder if there are other things that they can do with Thinkspace. One of the oft heard requests is to have highlighters to highlight the especially important things on the card or canvas. This can also take on a variation such as having a tool that reduces the information on a card to the most important bit. Being able to condense the information on a card would highlight the needed information as well as save space on the canvas.

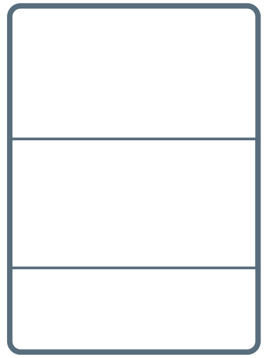




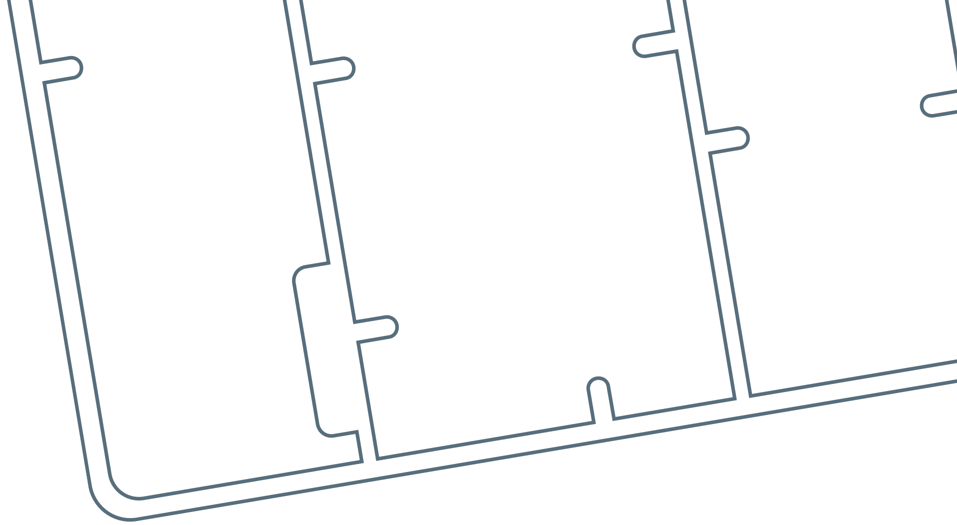
Facilitate Organization of Cards

Thinkspace is a tool that operates spatially. The implication of this is that canvas management tools are very important to help users shape the space however they would like. Currently, users can place cards wherever they like on the canvas in whatever organization they please. However, during our user tests, we noticed that users often tried to align cards with each other. Organizational tools such as snapping and various alignment options would be very welcomed for users who require them. Some participants also talked about creating flow charts or diagrams; there can be a flow chart tool to help students achieve that.

Format Card Content

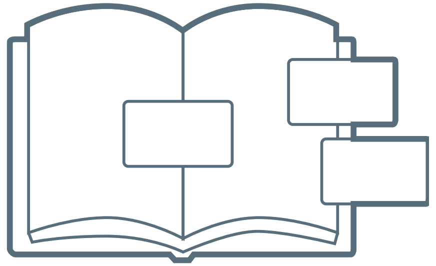


Currently, the information on definition cards is identical to the glossary pages in Inquire. These glossary pages often contain the definition of a concept as well as its structure, parts, and more. To view all of this content, the user has to expand the card to an unmanageable size. The information on these cards should be formatted differently to use the space given as efficiently as possible. Adding a scroll view would also help with reducing the size of the card.



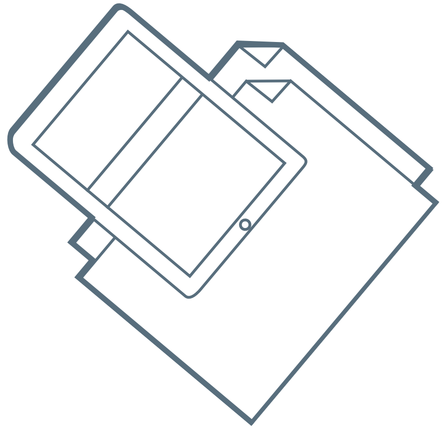
Link Content to the Textbook

Another idea that arose from our user research was the need to put some of the cards in context. Some users wished to look in the textbook to see the surrounding information about a concept, diagram, or question. Linking the cards back to the textbook would be a useful feature for users and would be an easy interface addition to the cards once SRI completes work on linking the knowledge base to the textbook.



Import Notes

Since Thinkspace is incorporated into Inquire, it would be useful to import the notes and highlights the user made in Inquire while studying into their Thinkspace while working. This way users will not have to duplicate work or worry about syncing Inquire with their Thinkspace.



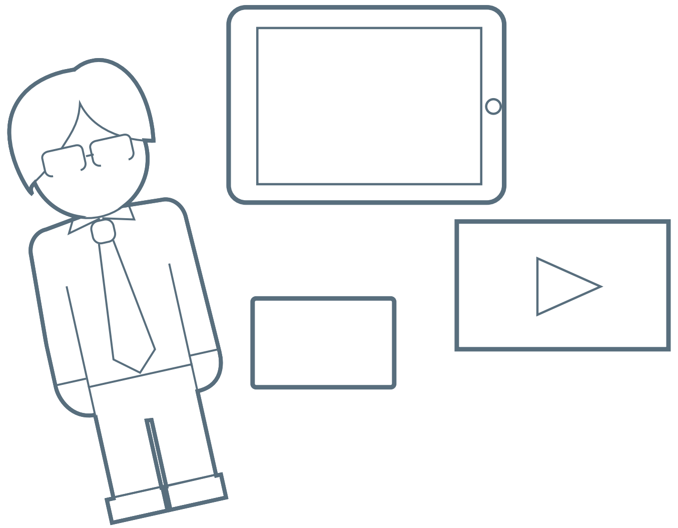
Think Social

We built an excellent single user environment to help students solve complex problems.

Adding social features would be the natural extension to this idea. As we speak to students and teachers, many expressed the desire to either share their work with each other, or to ask for help from their teachers. As Thinkspace is designed for laying out the user's thought process, it would be a natural fit for sharing such information.

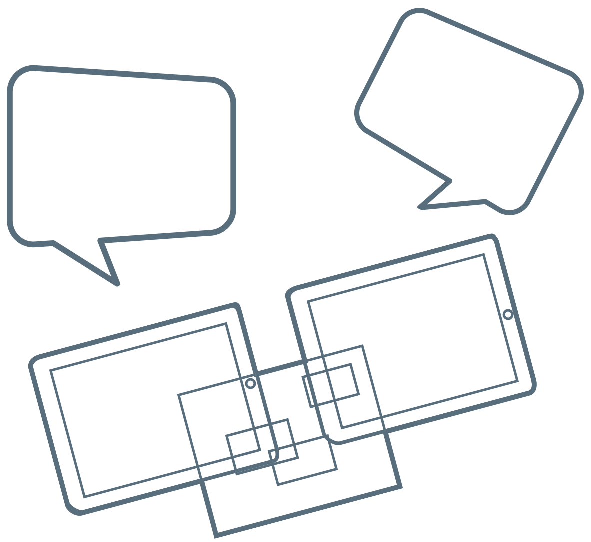
Our main focus so far has been to make the base Thinkspace platform as compelling as possible. In this section, we explore many of the ideas that we had in mind for allowing students to share their Thinkspaces. These ideas are based on our research and feedback from students and teachers during our user tests.

To better envision how Thinkspace can be beneficial to teachers and students, imagine a scenario:



Mr. Smith uses Thinkspace to distribute focus questions to the class every week. The question this week reads, *In the absence of oxygen, what would happen if you decreased the pH of the intermembrane space of the mitochondrion?*

To help his students get started, he decides to preload Thinkspace with some content. Mr. Smith adds a card with *What is oxygen's role in the electron transport chain?* as a prompt and a brief video clip on chemiosmosis. Knowing that his students just completed the chapter a week ago, the material will help the students jog their memory to complete this question.



Jessica, a student in Mr. Smith's biology class, opens up Thinkspace to attempt the focus question. She sees the content Mr. Smith has added to the Thinkspace and adds her answer to the card asking *What is oxygen's role in the electron transport chain?* Unfortunately, Jessica still doesn't understand how this information links to the answer of the original question. She notices her friend Jack is on the chat system. She messages him for help and turns on the "share screen" feature that enables them to collaborate on the same Thinkspace. Jack suggests looking into the video that Mr. Smith put in about chemiosmosis. After watching the video together, Jessica and Jack discuss how it's related to the question. Jack suggests that decreasing pH means more H+ and that this could have an effect on chemiosmosis. They deduce, after discussing the content on their Thinkspace canvas, that more H+ in the intermembrane space means more ATP production.

Jessica and Jack have figured out a significant part of the question together, but still have to piece together how the absence of oxygen affects the outcome. They decide to ask Mr. Smith for help. Jessica taps on the Ask the Instructor feature and the Thinkspace is sent to Mr. Smith for his review.

Mr. Smith receives Jessica's Thinkspace along with a note explaining where she's stuck. Mr. Smith looks at her Thinkspace to see what paths of inquiry she has already taken. He sees that Jessica has forgotten to consider the role of the electron transport chain in chemiosmosis and drops a card with the definition onto the canvas. He sends the Thinkspace back to Jessica, where she can see his hint and continue working on the problem.

Teachers are especially excited about the potential that a social component to Thinkspace could be beneficial to their teaching.

Here, we hope to list some ideas that would be helpful in thinking about social integration in the context of Thinkspace. We hope to cover the spectrum from teacher to student interactions, and from inside to outside the classroom.

Helping Your Peers

Since Thinkspace captures the paths of inquiry that a user takes, it has a valuable potential to communicate these research and synthesis decisions to other people. We envision a scenario in which a canvas contains all the necessary information for a focus question, but does not directly give the answer. By allowing this canvas to be shared, other students have the opportunity to make sense of the information and synthesize a solution independently.

Screen Sharing

Currently, when a student is stuck, the student will go to their teacher or friends for help. To effectively help the student, the teacher first determines the student's current understanding of the domain and then provides help tailored to the student's understanding. While using Thinkspace, if a student needs help, they should be able to share their current Thinkspace with the teacher since it shows their work up-to-date. By scanning the student's Thinkspace, the teacher can see the student's thought process, what the student has already uncovered, and possible misconceptions the student may have. This will allow the teacher to provide suggestions and guidance the student hasn't yet considered and correct any misunderstandings. The teacher would also be able to manipulate the student's Thinkspace to help guide the student.

More than Just a Question Solving Tool

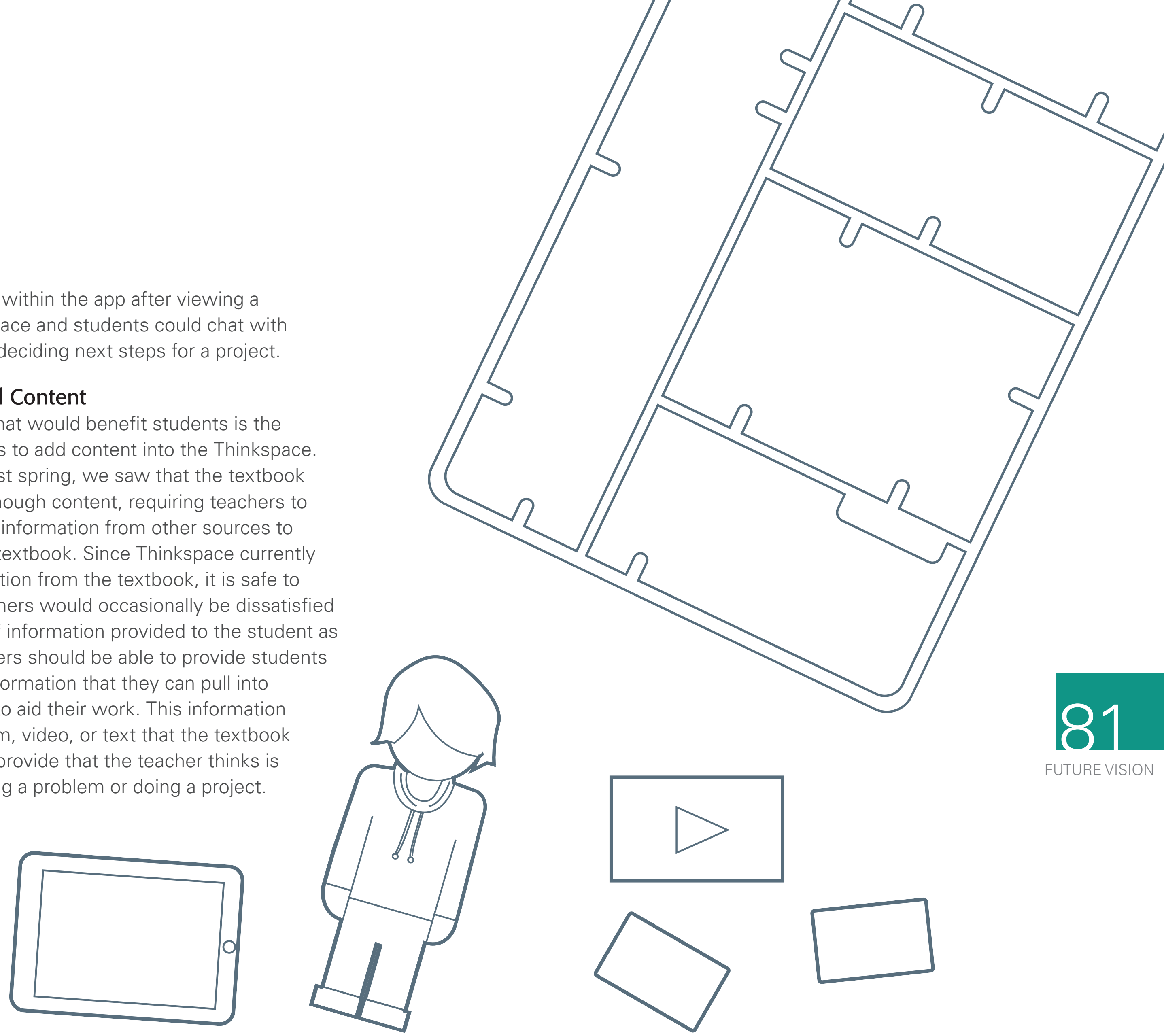
Sharing screens would also allow for other uses of the Thinkspace, such as group work for projects. Students could share their Thinkspace with everyone in their group and have everyone modify it concurrently. This would allow for easier group collaboration. If a group were to turn in their Thinkspace, the teacher could see which student contributed what and would be able to grade each person in the group more accurately reflecting their contribution to the project.

Chat

Allowing students to chat with whomever they are sharing their Thinkspace with would provide added support to students. Teachers would be able to communicate their suggestions within the app after viewing a student's Thinkspace and students could chat with each other while deciding next steps for a project.

Teacher-Injected Content

Another feature that would benefit students is the ability for teachers to add content into the Thinkspace. In our research last spring, we saw that the textbook did not provide enough content, requiring teachers to pull activities and information from other sources to complement the textbook. Since Thinkspace currently only pulls information from the textbook, it is safe to assume that teachers would occasionally be dissatisfied with the extent of information provided to the student as they work. Teachers should be able to provide students with additional information that they can pull into their Thinkspace to aid their work. This information could be a diagram, video, or text that the textbook does not already provide that the teacher thinks is essential to solving a problem or doing a project.



Scaffolding Learning

In our literature review, we described the importance of the integration of learning science principles and technology.

Here, we describe a vision in which we use learning frameworks to help a student take advantage of Thinkspace to explore and solve complex AP problems.

Frustrated Students

Currently in Thinkspace, the general strategy for most students to solve a complex question is to start defining terms and then try to form a relationship between those terms. While Thinkspace offers several tools to help students do this, they might not always reach the answer due to one of several reasons. For example, many students in our user research focused on the distractor information in a question and failed to see what the question was truly asking, which affected their search strategy. Other students went down unreliable paths of inquiry and could not link their research to the answer. In these cases, Thinkspace does not offer much to help students find the solution. "Oftentimes, the students just can't come up with the proper answers in a timely enough fashion to move the lesson along. This frustrates the students instead of exciting their curiosity and interest. At this point, a live teacher would use verbal hints to give their students more direction" (Judd).

Learning Frameworks

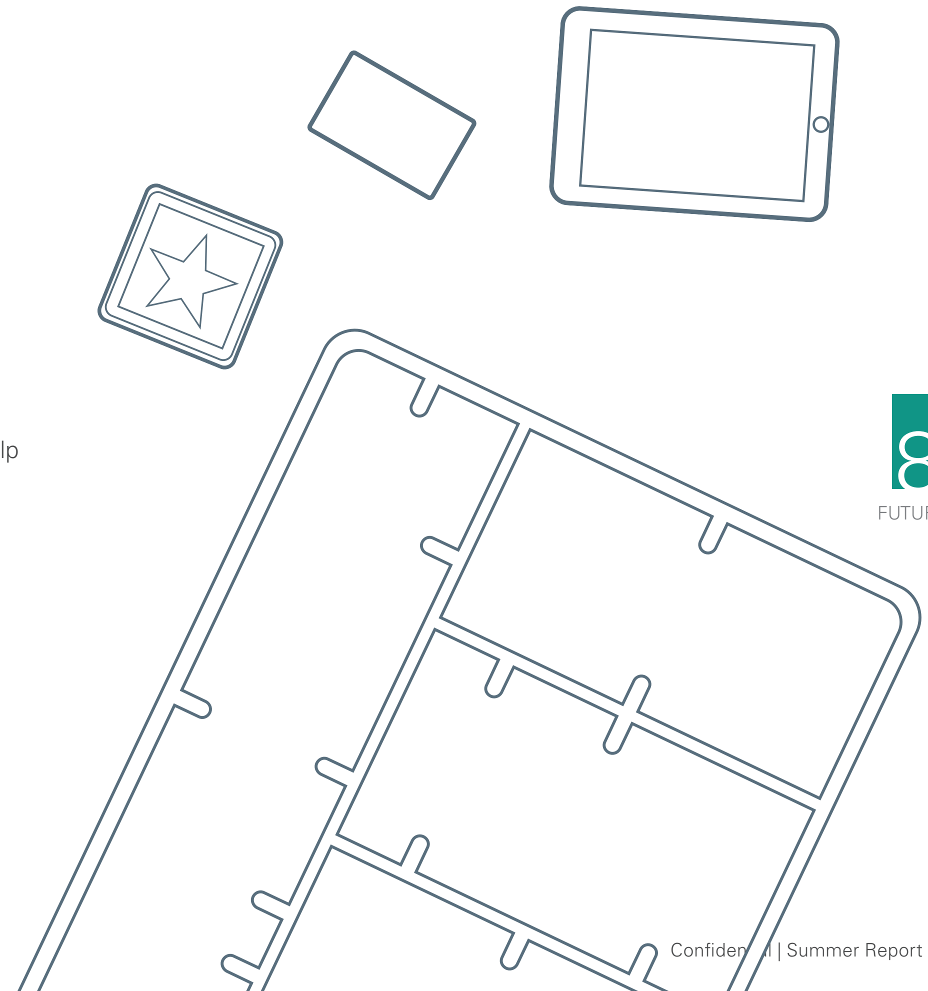
We considered a few different learning frameworks to implement that are considered useful for problem solving. One of these frameworks, the K-W-L method, explicitly prompts the students to mark down what they know, what they want to know, and what they have learned. We abandoned this idea after discovering it was more apt for reading comprehension than problem solving. The teachers we spoke to about this method also mentioned students' disdain for this method because it's so explicit, which makes the students feel like robots while filling out the chart. After searching through the literature and discussing with two teachers, we believed scaffolding questions would be a better way to help students since this is what teachers do all the time in the classroom and it provides the student with a feeling of ownership.

Scaffolding Questions

In the academic literature, several papers describe scaffolding questions as a proper way to help students move along in their work when stuck or frustrated. Scaffolding questions work exactly like the Socratic Questioning method used by teachers: questions are used to break the original problem into smaller and easier portions that the student can manage. In her paper Electronically Aiding Students' Learning, Judd explains how the use of scaffolding questions can benefit students: "Scaffolding questions force the student to slow down and pay attention to what they are learning. Enforcing a slower learning process rather than a 'get this done as quick as I can' process benefits the students."

Hints

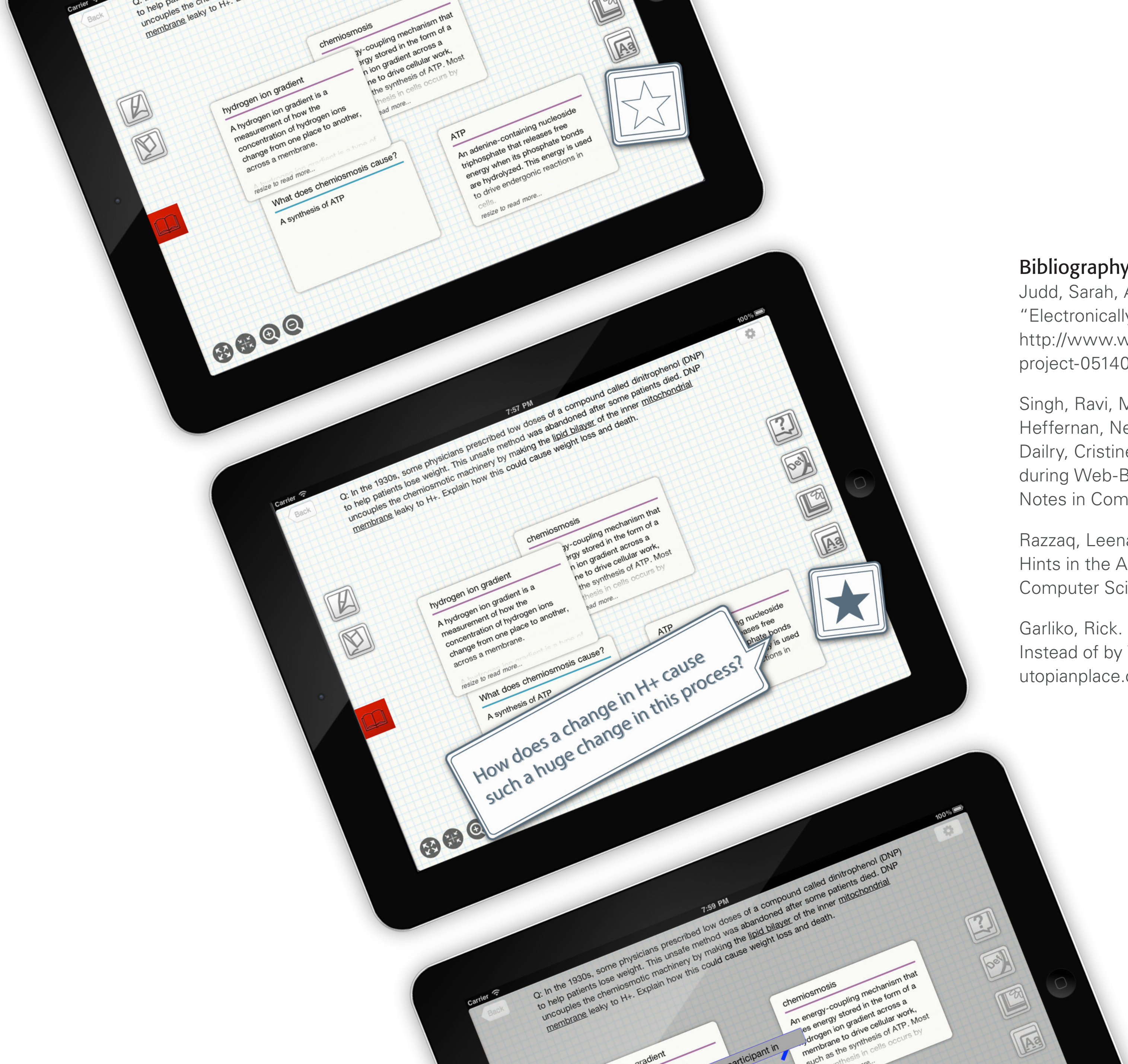
The literature also suggests that hints can be used to help move students along. While both scaffolding questions and hints lead a student to the answer, hints are passive in nature in that they are bits of information given to the student that reveal portions of the answer. When doing homework, hints help the student learn more than if doing the homework without hints. However, it's argued that scaffolding questions are better than hints since it requires students to interact with their learning. Razzaq found this to be true in some cases, but not all.



Integration into Thinkspace

We believe that in order to help the students who need a little extra guidance when performing their homework, Thinkspace should implement scaffolding questions. Taking what the student has already added to their canvas, the question prompts can ask questions to help the student move to the next logical step. For example, if nothing is on the canvas and the student asks for help, Thinkspace would prompt the student to try rewording the question and give a decomposed question. If the student has a ‘chemiosmosis’ and ‘ATP’ card on the canvas, Thinkspace could ask the student what is the role of each of these concepts in the overall biological process. Or it could ask how does chemiosmosis and ATP relate to each other.

To get these prompts, the student would press a button on the right side along with the other tools. A pop-up box would show with a list of questions to help the student. These questions are different than the suggested questions provided with the question tool. The suggested questions are questions about the concepts on the Thinkspace that ask about the structure and function of the concepts. The question prompts would instead ask the student how these concepts fit into the grand scheme of things or how it affects another process. The student can decide which of these question prompts is actually helpful and tap on any of them. If a student taps on a question, a card appears on the canvas with the question as the title of the card and the body is empty for the student to fill out as they find the answer. This gives the student a subproblem to solve to help them get to the answer to the original problem.



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FIN.

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The Carnegie Mellon Human-Computer Interaction Institute is an interdisciplinary community of students and faculty dedicated to research and education in topics related to computer technology in support of human activity and society.

The master's program is a rigorous 12-month curriculum in which students complete coursework in programming, design, psychology, HCI methods, and electives that allow them to personalize their educational experience. During their second and third semesters, the students participate in a substantial Capstone Project with an industry sponsor.

The Capstone Project course curriculum is structured to cover the end-to-end process of a research and development product cycle, while working closely with an industry sponsor on new ideas or applications that may work with their existing human- to-machine technology. The goal of this 32-week course is to give each student the opportunity for a "real-life" industry project, similar to an actual experience in a research/design/development setting.

Company sponsors benefit from the innovative ideas produced by the students, to fix existing systems or reach into new markets. Some companies also use this project as a recruiting tool, offering industry positions to the top producers in their project team.

For questions about the content, or to learn how to sponsor a project please contact:

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Appendix
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