team PYXIS *(pik·sis)*

Research Report
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Captivating and educating a new generation of American youth through the International Space Station.

NASA
HCII
Carnegie Mellon University

Executive Summary

Understand what excites high school and college students about space and science in order to bring NASA back into the home and educate a new generation of American youth.

In January 2011, our team of five Masters of Human–Computer Interaction students set out to create an application that would captivate students' curiosities about space by using the telemetry and scheduling information of the International Space Station (ISS) in an effective and compelling way.

Before we conducted our field research, we read relevant literature and analyzed analogous competitors to deepen our understanding of the domain. Our competitive analysis touches upon the possible ways NASA can improve the immediate engagement of their ISS application, and we highlight ways to help the application stand apart in its domain. The literature has improved our understanding of learning and engagement theories, educational theories, education technologies, and platform-specific design to ensure our application is educating students in an effective and exciting manner.

During field research, we utilized a variety of user research methods to gather rich data from high school and college students, educators, NASA flight controllers, and space enthusiasts. We highlight the process and methodologies we used to provide a clear picture about our research objectives when interacting with each participant group.

Through the analysis of our data, we have gathered valuable insights to create recommendations that will guide our design decisions when creating an application for the ISS. These revelations were encompassed in four big ideas:

1. *Captivate Students' Attention (pp. 38–46)*

From our classroom observations, we learned that the best way to capture students' attention is by sparking their curiosity through a breadth of interesting questions, stories, imagery and conversation-starters based on familiar knowledge. Literature and teacher recommendations suggest that using visuals and presenting material in a hierarchy are two successful techniques of attracting the attention of a diverse group, with different levels of knowledge and motivation.

2. *Provide a Visceral Experience (pp. 48–58)*

We observed that students favored subjects and activities where the learning was experiential and related to their world. Strong presentation that brings the content alive for students allows them to experience its real world dynamics. It enhances the impact of the content, but also helps them relate what they are learning to their world and what they know.

3. *Relate to Their World (pp. 60–68)*

Real-world qualities provides students with a stronger understanding of context, purpose, and value, making the information more meaningful and memorable for them, as do stories with high emotional appeal (e.g. building on thrill and camaraderie). These led us to identify several opportunities to make ISS data more interesting to students

4. *Manage Interruptions (pp. 70–76)*

Since it is likely that students may be using the application on the go or while surrounded by disruptions, the experience should fit the context of use and be adaptable to interruptions from the environment, system, and user. Our observations suggest that the interaction is most pleasant for the user when it adapts to their attention spans, does not interfere their workflow, and gives them control of their learning experience.

The findings and takeaways from these insights led to design recommendations (pp. 77–78) which will act as the key guidelines that will lead our design, wrapping up the research phase of the project. We began our visioning phase by revisiting all of the user research data and findings and conducted brainstorming sessions in which 70 rough ideas were generated. Three main design concepts (pp. 92–98) emerged from these ideas and aim to address different sets of design recommendations: a potentially educational and dynamic focus on scheduled activities, utilization of hands-on and immersive virtual experiences, and a social emphasis on communication between a student, his peers, and NASA. These themes, however, are meant only to serve as a conversation starter and are definitely not finalized.

Over the summer, we plan on continuing our design process to address our insights and settle on a concept that students will find exciting and educational. After a round of concept validation, we will start by creating paper prototypes to effectively test our design and will conduct two iterations of user testing before producing our final prototype. By deriving our design from what we've learned in the field, we are confident that our application will engage and captivate students and space enthusiasts from all walks of life.

Introduction

Images of man's first foray on the moon are instantly recognizable and indicative of an era when NASA was in every kid's heart.

Project Background

Our team is designing ISS Live!, an iPad application that uses real-time data from the International Space Station to educate and captivate a new generation of American youth.

Forty years ago, a generation of kids watched the space race eagerly: they listened to Kennedy's manifesto of space exploration, watched in awe as Armstrong laid the first human foot on the moon, and were astonished by the near-tragic heroics surrounding the Apollo 13 events. These events left an impression on this young audience, provoking a national interest in NASA and sparking a fascination with space in children. Many were spurred to pursue deep educations in scientific fields, and quite a few are continuing to deepen our knowledge of the universe at NASA today.

Fast-forward to today: with an increasing focus on the International Space Station (ISS), shuttle launches are ending and the visceral elements of space exploration are no longer being presented to students through the media and other outlets. Children often stop learning about space after elementary school, and many have no knowledge of what the ISS even is. "I think space seems really cool," one high school student said, "but I just don't know much about it."

ISS *Live!* is a project aimed at remedying that problem. We plan on designing an iPad application that communicates real-time ISS data (crew schedules and telemetry) in an effort to captivate the imaginations of high-school students and bring NASA back into the home.

Our team has researched this problem extensively, talking with flight controllers, educators, space enthusiasts, and our target audience of students over the past three months to develop an educational model that will guide the designs that we will prototype over the summer. Our vision is to bring NASA back into the lives of kids around the country, and our success will ultimately be measured in the students that our product inspires and educates.

"[Seeing the Apollo events] galvanized me to want to be an astronaut... and I knew I was going to have to be pretty educated. That's why I really believe in this project: y'all can do that for a lot of poor [kids] out there that don't have a vision."

— Dan, telemetry expert

Domain Knowledge

Literature Review

We analyzed over 40 relevant articles, books, and talks for insights on designing technology that support learning and invoke interest.

In order to invoke public interest in ISS scheduling and telemetry data, information must be conveyed in a way that our audience can easily understand and relate to. Since the learning process will primarily be driven by users, the interaction must be designed to allow them to take control of their learning and provide incentives to engage in this learning experience in the first place.

In light of this goal, we looked into various literature whose takeaways fall into four topic areas: Learning Theories, Engagement Theories, Educational Technologies, and Platform-Specific Design.

Our research revealed several insights about the learning process and tactics for designing experiences that sustain interest and support learning. The findings left us with a stronger understanding of qualities that are shared by effective learning environments and educational tools. This section contains summaries and key highlights from these areas.

Learning Theories

With the sharing of real-time scheduling and telemetry data, we anticipate our application to be information-heavy and possibly containing content unfamiliar to the end user. Understanding how people synthesize and learn information and what principles underlie successful teaching methods can help us design means of communicating information effectively.

Two key takeaways emerged from our literature on learning theories:

Connecting Prior and New Knowledge

One of the key differences between a novice and an expert in a field is that an expert has developed central organizing principles that they can generalize and apply across different experiences (Fosnot, Kam). In order to help a novice develop this ability, they must be guided to relate information to prior knowledge; this also allows them to transfer and apply the learned material correctly to different situations (Kam). It has been shown that students who are given a framework for understanding information develop a better understanding for those concepts (Kam).

Realistic Situations and Social Interactions

Since our application may not always be used in a formal education setting, the constructivist theory of learning provides relevant guidelines. A constructivist learning environment is driven by the student, since people generate knowledge and meaning from the interactions between their experiences and their ideas (Wikipedia). It advocates embedding the learning experience in realistic contexts, allowing the student to err, and then encouraging self-awareness and reflection (Fosnot, Wilson). In doing so, the material gains a sense of context and meaning. Constructivism also encourages education through dialogue and social interaction; this exposes the student to alternate solutions and perspectives. Justifying and communicating their ideas with their peers forces the student to gain a deeper mastery over the subject material (Fosnot).

Educational Technologies

Promoting Participatory Learning

In the vein of using technology to make information fun and learnable, lessons from educational technologies apply to our application. Takeaways from literature in this area include the "Seven Good Practices" of effective teaching that educational technologies should support: for example, utilizing active learning techniques ("learning by doing"), providing prompt feedback, and respecting diversity of talents and learning preferences (Chickering, Chiong, Robertson, "Top Five ways to Hook Kids into Learning"). Versatility is crucial in catering towards different types of learners, but is also important in allowing users to easily return to the content if they tune out (Strommen).

Additionally, combining education and entertainment is sometimes mishandled because it often leads to an approach that silos the two: the fun is separate from the education (Resnik). The entertainment aspect engages the user, but the educational aspect leaves the user to be a passive spectator. As such, it misses the point of creating an engaging learning experience. Instead of pursuing the edutainment concept, one should attempt to design an action-oriented "playful learning" experience looking to children and science museums' use of technology for inspiration (Resnik). Across the board, experts concur that educational technologies should create such participatory experiences (Chickering, Fosnot, Resnik).

Assessing Effectiveness via Student Performance

Another interesting highlight from the articles points out that assessing the effectiveness of educational technology cannot be done by traditional usability tests because the user is learning content through the medium instead of just interacting with it. As a result, summative evaluation should be used to assess the design of the product (i.e. users' performance in accomplishing tasks should speak to the effectiveness of design and delivery, Mayes, Strommen).

Engagement Theories

Dynamics of social media, online communities, and mobile consumerism reveal effective ways of building social traction and drawing user participation through value models.

Social Factors

Across literature, we learned that social factors that make people feel special and part of something epic or provide intrinsic rewards (such as reputation and status) as opposed to monetary rewards are powerful incentives (Kraut). Presenting a sense of urgency (e.g. through countdowns) motivates users to act quickly, and leveraging socially desirable characteristics increases their chances of participating in the system (Kraut, Priebatsch). One convincing use of social influence involves allowing undecided people to observe the actions of current users. Nothing speaks more about the product's value than another user's reaction (Porter).

Reducing Barriers to Engagement

If the system reduces the hassles to get involved and directly takes the user to main experience, users are more likely to sign up (Porter, Priebatsch). Effective systems use the strategy of presenting the benefits and features of a product in increasing depth in order to cater to the varying levels of motivation of potential users (Porter). By having an "elevator pitch" at the forefront, then an explanatory section for those who want to go beyond the superficial, and finally an option to learn even more, the product is less likely to turn off potential users at the critical first encounter ("iOS Human Interface Guidelines," Porter).

Regardless of the tactics used to initially entice a user, long-term engagement is often a result of a product's delivery on expectations.

Giving Users the Power of Action

Computers are an ideal medium for interaction because their properties afford immersion, agency, and transformation, which can create an enjoyable experience for the user (Murray). Interactivity involves a rich and believable environment, a sense of realism that motivates users to participate, and a variety of results that change with different actions so that users feel involved (Murray, Priebatsch).

It is an interesting parallel how these components of interaction apply to the real world. With the ubiquity of mobile technology, users are no long passive recipients of services (Prahalad). By generating content or other behavior, they also give value back to the service providers in a "co-creation of value" (Prahalad). Enabling end users to play an active role in shaping the service shows that a mutually-beneficial service model underpins not just business success but also user satisfaction (Prahalad, Priebatsch).

Platform-Specific Design

The medium through which the application is delivered plays a strong role in shaping the user's experience because each type of technology has its own appropriate context of use and "personality." Web is good at social and semantic relationships (people and content), and mobile platforms are better for spatial (place) and temporal (time-sensitive) contexts of use (Hinman). With qualities of both web and mobile, tablets aim of creating a relaxing, "lean back" experience (Stroud). Its form is portable (but not necessarily designed for time-crunch usage) and more informative (but not necessarily designed for intensive tasks).

Aspects to keep in mind when designing interactions for a visual interface (particularly a touch-screen tablet), include:

- *Designing for context of use:* accommodating for partial attention, interruptibility (Clark, Hinman)
- *Brand:* having a signature interaction that sets it apart from other applications (Myers)
- *Memorability:* lessons learned, because users remember best and worst experiences (Myers)
- *Discoverability:* tactics to lead the user discover novel interactions, like meaningful gestures for touch interfaces (Clark, Ginsburg, Stroud, Wroblewski)
- *General usability:* designing for touchscreen interfaces, considering screen size and available input methods ("iOS Human Interface Guidelines," Reichenstein, Wroblewski)
- *Cultural awareness:* know your user (Hinman)

Competitive Analysis

Analysis of analogous products revealed that unique interactions and immediate engagement characterize popular products and that benefits of social interactions are yet to be tapped in this domain.

We looked at analogous products in the market for inspiration to learn from their strengths and weaknesses. Due to the goals of this project, we selected mostly iPad applications and a web application, all of which aim to inspire users to explore scientific data in different ways. Using the criteria below, we visualized our product comparison and identified trends and opportunity gaps.

Criteria for Assessment

We first analyzed these products over a wide range of criteria including rating, pricing, feature offerings, and target users. Of these, we selected a few relevant items, highlighting the features used to communicate information and draw users to the application. In this analysis, we also included key differentiating features of the applications (e.g. signature interactions and use of novelty) and/or features that contributed to the applications' popularity. Finally, we assessed whether engagement or communication tactics discovered in the literature review (e.g. use of social influence, user-generated content, virality factors) were utilized by these applications. Together these analyses revealed gaps among existing products in the marketplace, revealing design insights and potential opportunity spaces.

Products Assessed

Our selection consists of those that were especially award-winning and popular, alongside the core NASA application.

NASA HD

An iPad application that provides space-related pictures, clips, news articles and details about NASA-related topics. Although the NASA application is also available on iPhone, we limited our competitive analysis to the iPad version.

Eyes on the Solar System

A web-based interactive application designed at the Jet Propulsion Laboratory. Users can explore the Solar System in 3D using real NASA mission data. The user can follow trajectories of various spacecrafts and visualize the Solar System moving at different speeds.

Star Walk

An augmented reality star-gazing application that lets users explore constellations and learn about astronomy on the iPad. It won the Apple Design Award 2010 and was a featured application for 2009 and 2010. Designed by Vito Technologies.

Solar Walk

An iPad application that allows users to explore the solar system in 3D (with and without glasses), including real-time trajectories of the Earth's artificial satellites. It was a featured app for 2010. Designed by Vito Technologies after Star Walk's success.

The Elements

An iPad application that presents the users with an interactive periodic table of the element. Users can interact with individual elements in 3D (with glasses) and learn about their various properties. Designed by Theodore Gray.

PRODUCT	Usability (Heuristic Evaluation)	Immediate Engagement	Accessibility	Novelty	Data Visualization	Interactivity	Community/Social Interaction	Incentives to Return	User-generated Content	Price	User Rating (out of 5.0)
NASA HD	○	◒	◒	○	○	◒	◒	○	○	Free	3.5
Eyes on the Solar System	●	◒	●	●	●	●	○	○	○	Free	N/A
Star Walk	●	●	◒	●	●	●	○	●	○	$4.99	4.5
Solar Walk	◒	●	◒	●	●	●	○	○	○	$2.99	4.0
The Elements	●	●	◒	●	●	◒	○	○	○	$13.99	4.0

VALUE CRITERIA

● = high
◒ = moderate
○ = minimal/none

Insights

Novelty

The highest rated applications in the chart all include novel forms of interaction; this supports our takeaways from the literature review, where we learned that “signature interactions”reinforce brand and such unique features not only help the product stand out from its competitors, but also increase memorability of a application. If used successfully, they make for a delightful experience that the audience learns to recognize the application by. Based on customer reviews for Star Walk’s GPS and accelerometer-based augmented reality and The Elements’ use of interactive 3D visuals, we could see that unique interactions indeed contributed to the popularity and “cool factor” of the application. It is worthy to also note that both of these applications were praised for their elegant presentation of visuals as well as their ability to make the interaction feel real to users.

Social Interactions

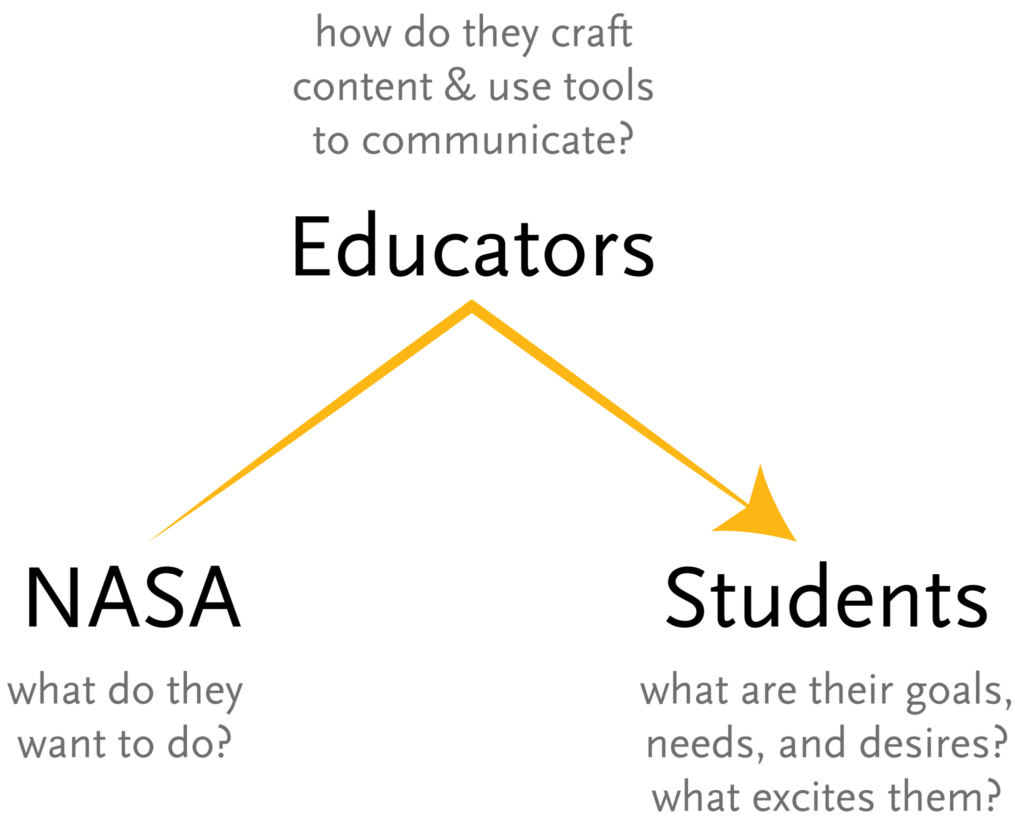
The literature review mentioned that agency, social influence, and social interactions are effective to enhance user engagement, educational effectiveness, and virality; however, these applications focus mostly on creating rich individual experiences. The NASA application is the only one of these to come close, but it provides questionably functional access to the Twitter application.

It is possible that the area of social interactions is an underused opportunity space in this domain. If we want to engage users and help them learn material, allowing for user-generated content or social interactions to facilitate individual exploration seems to be a fertile ground to explore and stand out in the market. Additionally, factors that make the application easier to share and recommend to friends (“virality”) would help the application spread.

Immediate Engagement

We observed that the applications with the highest ratings contained features that made them more conducive to usage. Some applications particularly stand out from others by giving the user motivation to return to the application. Star Walk, for instance, notifies the user when there is a new picture of the day with an indicator that increases the count each day the pictures are not viewed. Additionally the application supports day-time exploration and viewing at night, expanding the appropriate context for use. Star Walk, Solar Walk, and The Elements are also conducive to usage because they directly take the user to the exploration page instead of providing a menu or a plug-in installation preface. By immediately immersing the user in the main experience, these applications reduce the barrier to user engagement.

Field Research


how do they craft content & use tools to communicate?
Educators
NASA
what do they want to do?
Students
what are their goals, needs, and desires? what excites them?

Research Overview

After careful consideration, our field research focused on three demographics: flight controllers, educators, and students.

Initially, our team was charged with designing a product that would appeal to the general public; however, our research had to be more targeted in order to for it to be conducted in a reasonable amount of time. To better understand the target demographics of potential users of ISS *Live!*, we attempted to better understand NASA's mission of education. As seen in the diagram to the left, NASA regularly works with educators, both internal and external, to share work that NASA does with students of all ages.

In a similar manner, we split our research into three key demographic groups: NASA flight controllers, educators from schools and NASA, and students.

Students still represented a rather large demographic, so it was necessary to further pare down the definition into a more reasonable size for field research. Due to the complex nature of the data that would be presented, students would have to be at least in high school to fully understand the material. It was also determined that the most ideal students would be those still attempting to build their identity—ones who had not yet decided their careers and could be interested in a science-related one. We therefore focused our research of students on tenth and eleventh grade high school students and college freshmen.

13 flight controllers

NASA

10 educators

teachers

NASA

23 students

high school

college

7 space enthusiasts

various

53 total

4 high schools

school type

private

public

median income

high

low

Demographics

To ensure the collection of valid data across several demographics within our targeted groups, we carefully selected research participants with a range of criteria. All groups were represented by a mix of male and female participants to minimize gender bias in the research.

Flight Controllers

We primarily researched flight controllers on the planning team at Johnson Space Center. To add a wider range of information to our research, we also conducted interviews with flight controllers working within other areas of NASA. These flight controllers represented a breadth of knowledge in our research ranging from the environmental systems of the space station to shuttle mission planning (a drastically different process from station planning).

Educators

For each high school visited by the team, one teacher was observed and interviewed. We focused primarily on teachers to observe different teaching styles of the same material. To ensure these teaching styles were not completely content-specific, one astronomy class was also observed.

Students

Special care was taken with students to ensure a diverse range of demographics were reached. Research with high school students took place in their school, so we developed criteria for selecting schools. Of the four schools visited, two were privately run and two were local public schools. Two of these schools were also lower-income schools within the city and two were higher income schools in the suburban Pittsburgh area. From each school, the students themselves were also selected based on predefined criteria.

To avoid any bias caused by only looking at students interested in space exploration, only 50% of students researched described themselves as primarily interested in math or science. The remainder of the students represented a wide variety of academic interests.

For practical reasons, all college freshmen were selected from the Carnegie Mellon University undergraduate student body. Similar to high school students, these students were selected based on their academic interest with two of them having a declared major in liberal arts and the other two in science or engineering. Each of these groups included one male student and one female student.

Space Enthusiasts

In addition to our three key groups, we took the opportunity to interview those interested in manned spaceflight to develop a richer understanding of what generated their enthusiasm for the field. These individuals were simply interviewed based on willingness and availability.

These individuals represented the whole gamut of space enthusiasts from a CNN space reporter to a digital effects guru in the film industry with a special passion for space exploration. Contact with many of these individuals came from chance encounters. Nonetheless, these interviews provided valuable discoveries into how space exploration reaches a wide variety of people in many different career paths.

Methods: Flight Controllers

Contextual Observation

To better understand the telemetry and scheduling data that flight controllers work with on a daily basis (and the type of data ISS *Live!* would use), we observed flight controllers during their normal work. The method used to conduct this research was based on Contextual Inquiry where the work practices of individuals is observed in their natural environment. In this method, the researcher acts as an apprentice to the person being observed. Contextual Inquiry also dictates that these observations must always occur when and where the person would normally be working to best understand the context of work. Prior to the observation, researchers conducting a Contextual Inquiry set a focus to ensure that all questions being asked and observations made are relevant.

Our method with flight controllers differed slightly from a traditional Contextual Inquiry due to the high demand nature of their work. Normally in contextual inquiry, the researcher would ask questions as they arise and interrupt the participant frequently. Because the flight controllers being observed were working in the front and back rooms of mission control, they could not be interrupted as frequently, so questions were noted and asked when appropriate. Particularly in the front room, where many other flight controllers were also performing critical work, some questions were answered by other flight controllers during interviews afterwards.

A flight controller in ISS Mission Control sits at his console in Houston, Texas as we observe.

Activity Affinity

We also used flight controllers to get a better understanding of the frequency of activities and telemetry as well as their personal interest in these data. To this end, we had flight controllers write down the most frequent activities as well as the activities they found most interesting down on post-it notes. We used a method known as affinity diagraming to help make flight controllers organize the post-its. In making an affinity diagram, ideas are written on cards and then collected into groups. Groups are then given titles and sorted into larger groups (which in turn are titled). This type of diagram can provide an easy way to hierarchically organize data.

For the activity diagrams, the post-its were simply grouped by which flight controller wrote them down. Flight controllers first put the most frequent activities up in order of frequency. Following that, they created a similar diagram ordered by their interest in the activities.

For telemetry, a more traditional form of affinity diagraming was used where flight controllers helped list the various types of telemetry used onto post-it notes and then asked flight controllers to help cluster them into groups.

Flight controllers Aaron and Greg organizing post-its on the whiteboard in the order of their interests.

Methods: Flight Controllers

Interviews

Flight controllers represent a passionate group of individuals who have devoted their careers to manned spaceflight. Because of this, we took the opportunity to better comprehend what inspired them to pursue the career they did. We asked flight controllers to share the experiences that led them to their current position as well as what first got them interested in space exploration.

We also asked flight controllers to share stories about their job, and used these stories to understand what events were particularly salient to flight controllers to discover what they found most interesting.

Finally, some flight controllers from sites we could not visit only interviewed on the phone to help provide a richer set of data. These flight controllers were asked the same questions as flight controllers interviewed in-person as well as asked to describe the activities and telemetry they would have used in the affinity diagram activity.

Clifton conducting an interview with a flight controller on-site at Johnson Space Center.

Our team toured mockups of the ISS in order to experience the station firsthand.

Methods: Educators

Contextual Observation & Interview

When visiting high schools, we observed classes to understand how teachers convey complex information to students. Like our observations with flight controllers, we used a variant of Contextual Inquiry to conduct the research. Because we could not interrupt the class, we simply recorded all of our questions and took some time with the teacher after the class was over to go through the questions in a retrospective fashion. This allowed us to have an interview that was still based in context.

We also asked teachers and NASA outreach personnel various questions about their teaching techniques and styles. We wanted to understand what methods they found effective at reaching students and what recommendations they had for others. We also wanted to understand their use of technology in this process.

A chemistry class observation at Avonworth High School.

We observed NASA outreach personnel use a Microsoft Kinect game with a young class to explore the ISS and show what low-gravity is like.

Postcard Drawing Activity

To help students become more comfortable working with the group, we invited them to participate in a drawing activity during our observations. Students were provided with a large piece of paper with a postcard layout on it and asked to draw what they would share with their best friend about a hypothetical experience in space. Members of our team also made postcards to help the students feel less self-conscious about their drawings.

This activity allowed us to get an understanding of what students knew about life aboard the International Space Station, and what they imagine occurs onboard the station. We started the activity by providing them giving them the following background knowledge and scenario:

"You are an astronaut on the Space Station, and you want to share a glimpse this experience with your best friend on Earth. Here is a postcard, that you can send to him/her on Earth. What is the one thing that you would like to share? You can draw, write or express this in any way you like."

The students were given about 10–15 minutes to fill up and annotate the postcard. At the end, we had everyone present their postcard, starting with ourselves.

A few postcards from students, who often had limited knowledge of space (as evidenced by Ashwin's "SPACE THING" label above).

Methods: Students

Background Interview

Because our project involved the use of technology and scheduling data, we wanted to get a better understanding of how students used technology and schedules in their daily lives. When working individually with the students, we asked them a series of questions to get some basic information in these areas as well as inform later activities:

- What sorts of classes are you taking?
- What do you do outside of school?
- How do you keep track of everything you need to do?
- Do you use different tools for different purposes?
- Do you play any games? Which types are your favorite and why?
- Do you or any of your family/friends use a smartphone? Do you use any apps on it? Which ones do you use most often? Which are your favorite and why?
- Do you use any digital tools for learning? (Favorite sites? What does it help with?)

A Pyxis team member conducting background interviews with Freddie-Mae, a student, and Ms. Gomez, a teacher.

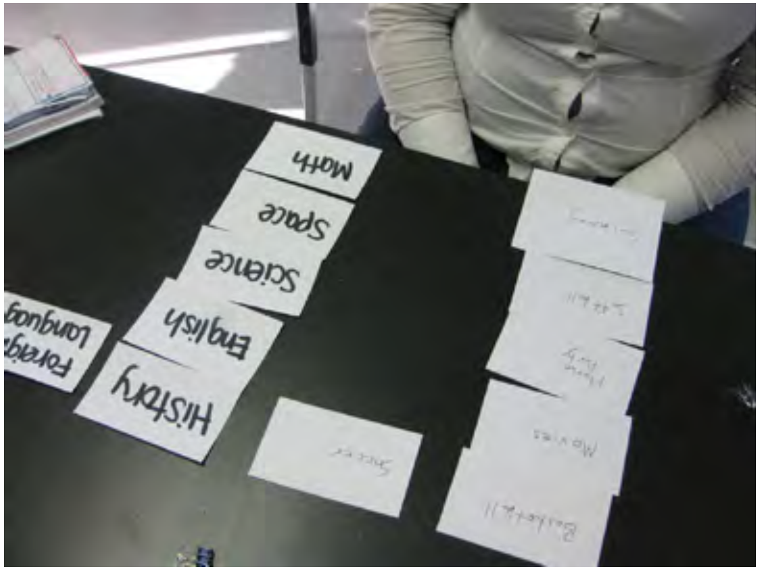
Methods: Students

Card Activities

In an effort to learn about the interests of students and why they find certain activities exciting, each student sat with a team member and was presented with a deck of cards with one for each activity in their life. Students were asked to look through the cards and sort them by how much they enjoyed each. This informed us about their current interests. We also took the time to have the student rank the cards according to which they wanted to learn more about or improve at. Finally, we had the students sort the cards according to how much time they invest in each activity. Each time students sorted the cards, we asked why they ranked the first two activities on their list at the top and why the last two activities were at the bottom.

We also made a deck of cards that had an activity or type of telemetry data on each card. Pairs of students were given these cards and asked to sort them into two piles: things they were interested in and things they were not. We encouraged the students to discuss the cards with each other and their rationale for each decision.

Originally, the second card activity used cards with various space pictures and headlines on them. However, this was refined during the research process to get more specific results based on our research with flight controllers on what activities and telemetry exists.



High school student Bryanna organizing her subjects and activities in order of how interested she is in them.

Methods: Students

Contextual Think-Aloud

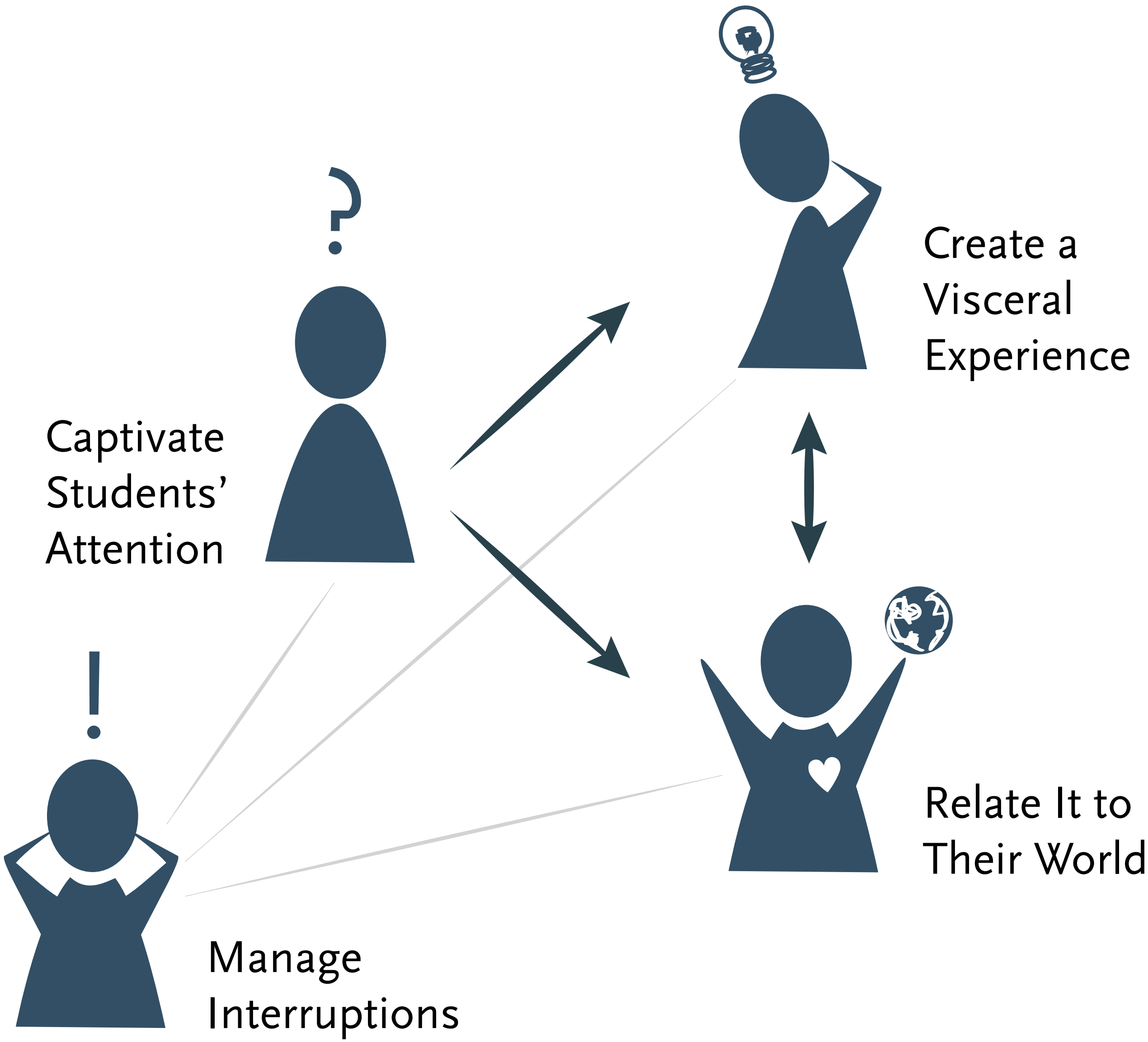
We interviewed college freshmen to understand the lifecycle of an educational application and observe them using existing applications in the problem space. We had students use a process called a think-aloud to study how they find and evaluate new educational applications. Think-alouds consist of having the participant say everything they think as they think of it. This allows researchers to know a user's entire thought process, including intentions and expectations, instead of just observing their actions. This protocol is typically used to evaluate prototypes of new interfaces.

For our research, we adapted the think-aloud as a way to observe students finding and using educational applications and websites in a natural context (their own devices in a campus environment). We had students go through the process of finding an educational application on the iOS App Store while verbalizing their thought process. Students were similarly asked to browse the web to find an interesting educational website and then verbalize everything they thought as they explored these sites.

We also invited students to use the NASA HD iPad application during the think-aloud to understand how students evaluate a mobile application and get data that would be standardized across all students.

A college freshman using the iPad to explore the NASA application.

Insights


Create a
Visceral
Experience
Captivate
Students'
Attention
Relate It to
Their World
Manage
Interruptions

Insights Overview

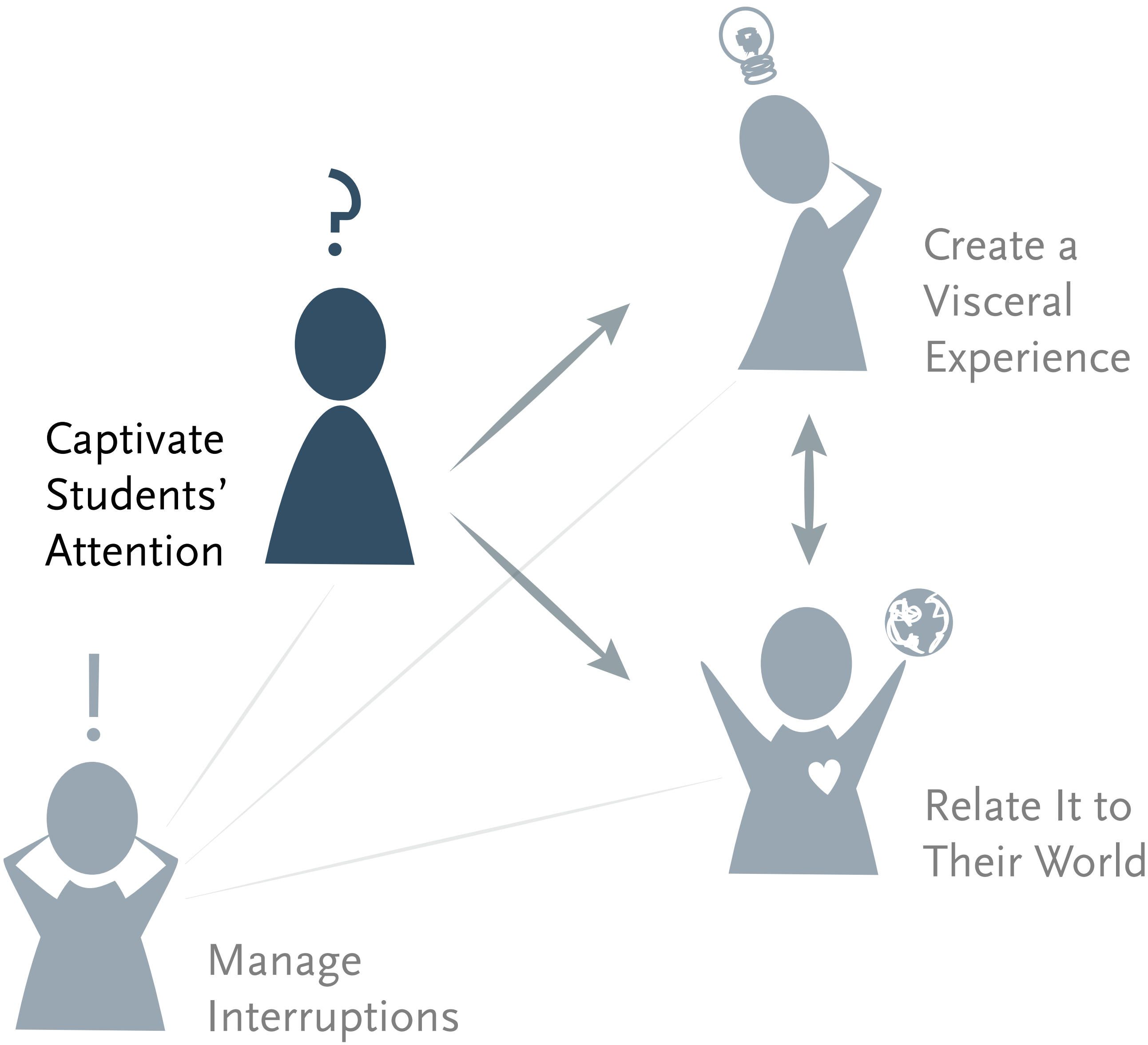
Our findings focused on four different aspects of an educational model: the need to captivate a student's attention, the possibilities of visceral learning experiences, the benefits of relating material to their world, and how to handle various disruptions.

We walked away from our field research with findings that emerged from all of the demographics we interviewed, and that hinted at opportunities for how we could make ISS information appealing to students. These findings converge into four key insights, which include:

1. Capturing students' attention
2. Providing a visceral experience
3. Relating to their world
4. Managing interruptions

We discovered that these themes could be combined to describe a journey of engagement: from a superficial level of attracting students' attention (1), to an internalized state that the student has been able to personalize (2, 3). In this framework, our fourth insight captures the breakdowns that could happen in this process, giving way to suggestions for handling disruptions to engagement. The diagram to the right illustrates the relationship of these overarching takeaways.

In each section, we go into depth, describing the supporting data, literature, stories, and ideas that led us to draw these insights. We also present recommendations grounded in these observations to illustrate how these insights can be incorporated into the upcoming design process.


Captivate
Students'
Attention
Create a
Visceral
Experience
Relate It to
Their World
Manage
Interruptions

Captivate Students' Attention

Evoke the curiosity of students by providing a concise means of capturing what is interesting and engaging about the topic and pushing it to the forefront through catchy headlines, stories, and imagery.

The seventh period bell rang. As the eleventh grade students settled into their seats, they were greeted by this unusual prompt on the whiteboard:

"Is it possible that the oxygen you are breathing right now was once breathed by dinosaurs?"

After they scribbled their responses into their notebooks, Ms. Gomez, their chemistry teacher, started calling on them to share their thoughts. As they discussed their speculations and theories about the composition of air and oxygen, Ms. Gomez led them on with questions, helping them connect their ideas with chemistry fundamentals from the past class. Eventually, the students discovered that they are, in fact, breathing the same air as the dinosaurs once did, due to the Law of Conservation of Matter: the topic of their lesson for the day.

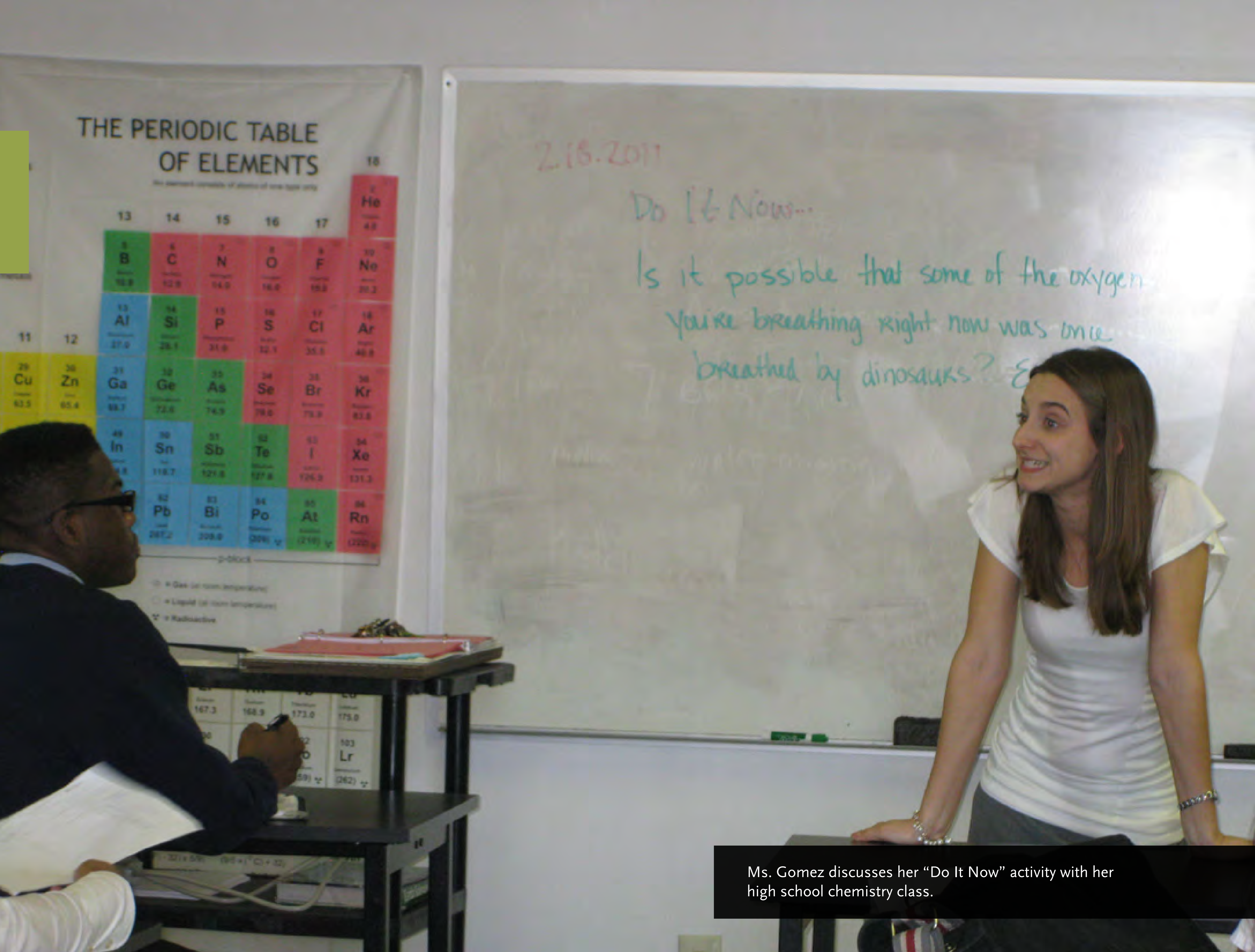
Each afternoon, Ms. Gomez begins her eleventh grade chemistry class with an activity she likes to call "Do It Now," in attempts to stir the curiosity of her students. On weekends, she spends a few hours browsing through articles on the internet and in magazines to come up current, relevant, and interesting conversation-starters related to the material she will be covering in that week's classes.

The technique Ms. Gomez uses to begin all of her lessons is what many teachers refer to as a "hook"—something that attracts attention or serves as an enticement. This engages students by getting them to think about the material that will be covered in class that day.

The concept of a hook illustrates the first phase of our educational model, which discusses different methods educators use to catch students' attention and obtain their initial interest for a given topic. According to our findings, there are several components that contribute to an effective hook. First, it is based on ideas that are familiar and understandable to students, but presented in a unique context. This allows them to recognize it, but adds the unfamiliar or mysterious aspect adds a "cool" appeal. Second, it caters to the diverse interests and knowledge levels of the audience. Using visual content and presenting information in layers are two techniques educators use to pique interest in new information.

Findings

1. Curiosity arises from familiar topics with a new twist.
2. Students have diverse interests.
3. Visuals universally attract attention.
4. Hierarchy of information facilitates browsing.



Ms. Gomez discusses her “Do It Now” activity with her high school chemistry class.

Captivate Students' Attention

1. *Curiosity arises from familiar topics with a new twist.*

Just as Ms. Gomez used a "Do It Now" question, Mr. Williams, a high school astronomy teacher, uses a "Picture of the Day" to kindle curiosity. All four teachers we observed introduced new topics with a catchy question, image, or activity that built on what students already knew. This tactic, according to the constructivist theory of learning, is an important component in the learning process because curiosity builds a desire to learn. Motivation is essential to learning, and more so in situations where students must drive their own learning experience (Hein).

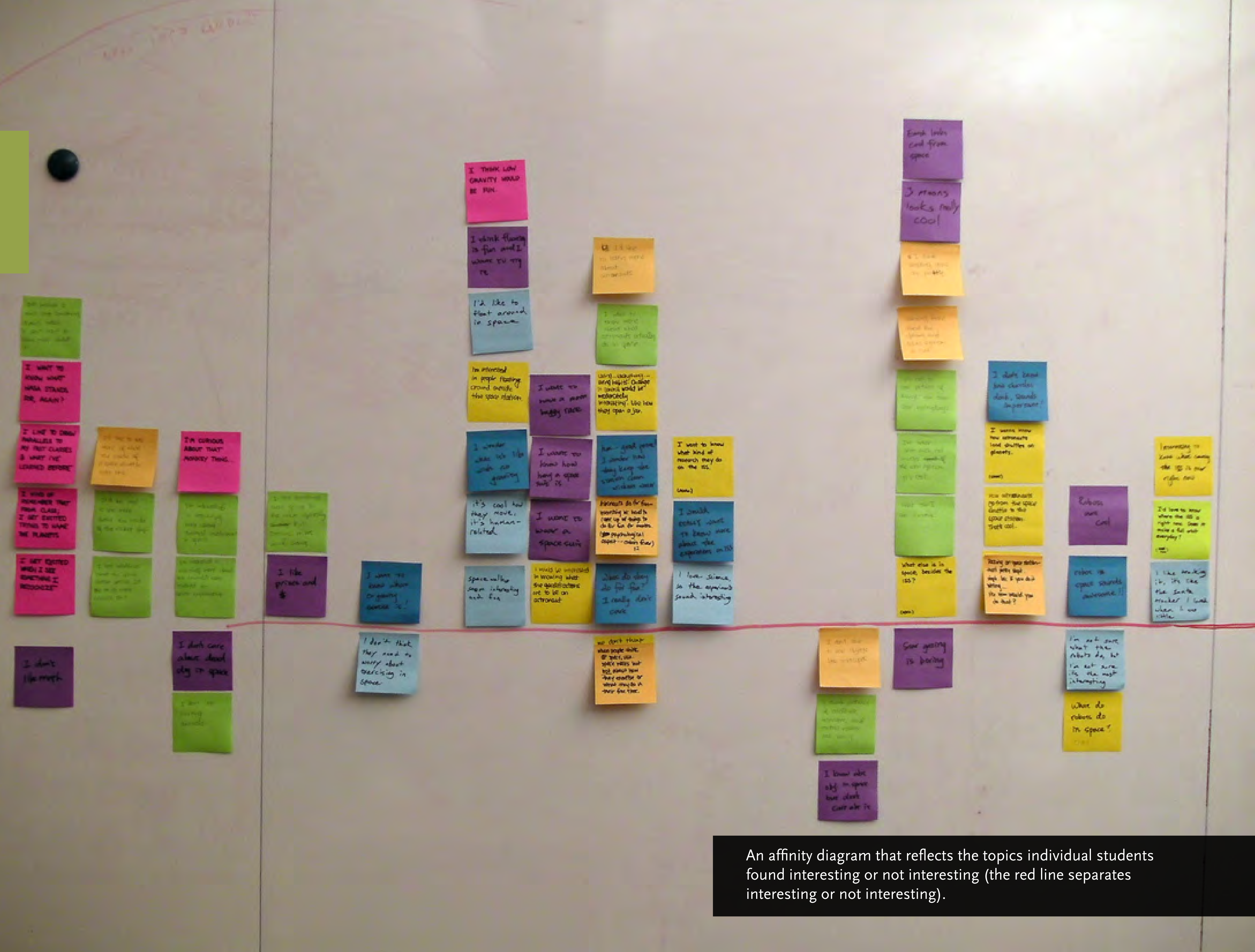
The card activities we did with high school students revealed that one of the major reasons behind why they found certain topics interesting and worthy of exploration was a sense of "coolness," stemming from unfamiliarity. For example, we often saw students interpreting seemingly obvious topics as mundane and boring. However, pictures of planets and nebulae they had never seen engendered strong interest. Kierra, an eleventh grade high school student, explained that she found close-up images of stars and the earth more appealing than images of telescopes because of it was not common for her. This statement reinforces the need to provide images that capture uncommon aspects of the ISS to draw the attention of students.

It's important to keep in mind that this appeal stems from the desire to know more about something that is understandable. For instance, students expressed a lack of interest in telemetry as a whole because they didn't understand what the term meant and the types of data it encompassed; however, when asked if they would be interested in knowing about how humid it is on the ISS or how far the ISS is from where they are standing, they placed those topics in the category they would like to learn more about. Furthermore, they discussed these topics in their participant groups and wondered about other related questions.

Based on the reasons students used to justify their ranking of certain image, topic, and question cards as more intriguing than others, we deduce that hooks should balance familiarity and novelty in order to be enticing. There should be a moderate level of novelty that offers the possibility to unveil something unexpected, but the material must also be understandable, and within a range that the student can make this leap of knowledge. From the data compiled from the card activities with the students, we believe that there is an opportunity to evoke that sense of curiosity by highlighting material users can comprehend in a new or interesting way.

Recommendation

Invoke curiosity with a familiar, but thought-provoking, topic.



An affinity diagram that reflects the topics individual students found interesting or not interesting (the red line separates interesting or not interesting).

2. Students have diverse interests.

Students were curious about extremely different things. As we probed them about their interests and curiosities, the stories and reasons that emerged were closely related to their personal values, and hence extremely diverse. For example, some students are curious about how the ground crew collaborates with astronauts. When presented with a question card about how many people it takes to send three astronauts to space, twelfth grade high school student Isaac immediately exclaimed, "This seems interesting! I really want to know how this coordination actually happens, and also this seems like a very critical task." In contrast, when we presented this to another high school student, Hope, we got a dramatically different response: "Of course this takes a lot of people. I think the stuff they do sounds like mundane chores," before putting the card into the "uninterested" pile.

Students also differed in the types of extracurricular activities and classes that they enjoy due to their varying interests. Derrick expressed his love for English and enjoyment for writing poems and short stories during his free time. Another student, Freddie-Mae, talked about her love for chemistry and desire to pursue a career as a forensic scientist. Both students lay on opposing ends of the spectrum when it comes to their love for space and science, which impacted the types of images and headlines that captivated their attention. Although the academic interests of the high school students are somewhat aligned with their structured coursework, there are no common traits observed across all 23 students we spoke to, regardless of school or gender.

As students varied in their knowledge and enthusiasm to learn more about different space-related topics, the hook and content should cater to this diversity in order to captivate the initial interests of these students. The upcoming topics explain two methods to address this challenge.

Recommendation

Offer a breadth of content and cater to the diversity of knowledge and interests levels.

A college freshman using the NASA application on an iPad looks for visual material, like the picture of the day and NASA TV.

3. *Visuals universally attract attention.*

Human perception is visually driven, and our research verified the importance of visuals in the context of learning. We showed students both picture cards and cards with headlines, and they overwhelmingly found images more appealing than the cards with text since their attention span for images was relatively higher than for text cards.

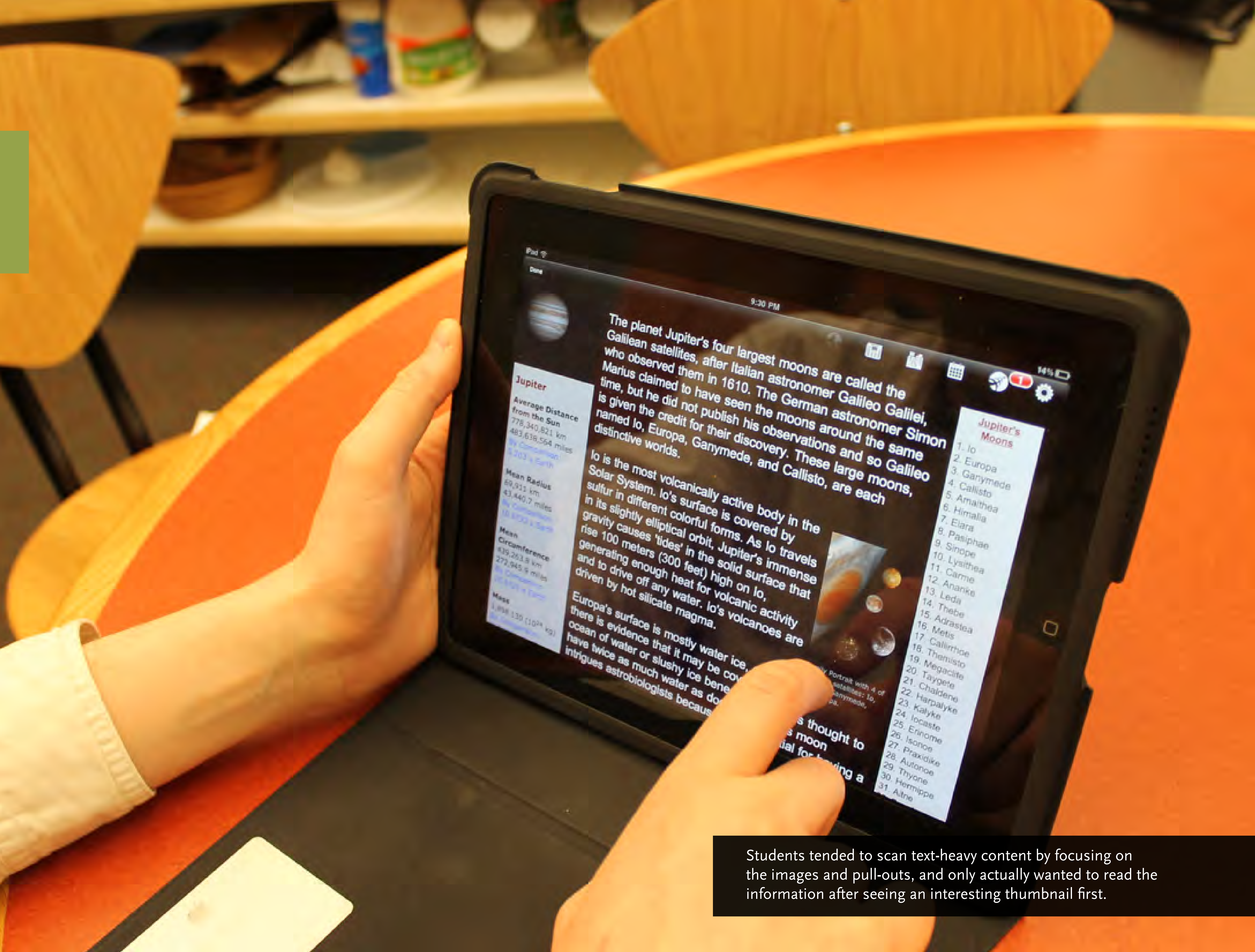
We also observed that students often looked at images to evaluate their interest in digital content. All of our freshmen participants had a longer attention span with visuals. One participant spent no longer than five seconds on text-intensive pages but would spend drastically more time exploring content when he came across image and video content. Also, when the students were browsing for interesting science websites or choosing article sections to read in the NASA iPad application, several participants used the associated pictures to decide whether they were intrigued to read further. All participants commented that the appearance and layout impacted their impression of the content.

Teachers have long leveraged this behavior to engage students. For example, high school astronomy teacher Mr. Williams always starts off his class with a picture of the day to draw students' attention. During a retrospective interview after a classroom observation, he discussed his technique to draw the interest of his students. He advised, "Make it visual. That's how you relate to their world and make that experience personal." Indeed, every single teacher we talked to mentioned visuals being a powerful tool to communicate knowledge and help them create a more personal learning experience.

Our findings support the claim that using strong, eye-catching visuals is universally one of the most effective methods of communication and capturing students' attention. For this reason, content should be communicated visually whenever possible.

Recommendation

Utilize imagery and visuals to make content appealing to students at first glance.



Students tended to scan text-heavy content by focusing on the images and pull-outs, and only actually wanted to read the information after seeing an interesting thumbnail first.

4. Hierarchy of information facilitates browsing.

We discovered that students tend to browse content layer by layer, supporting the advice of NASA outreach educators and industry web experts.

We observed students using digital applications like the NASA iPad app and saw a significant trend of browsing content hierarchically. They skimmed content using images, titles, brief descriptions, and pull-outs before reading body paragraphs and text-heavy content.

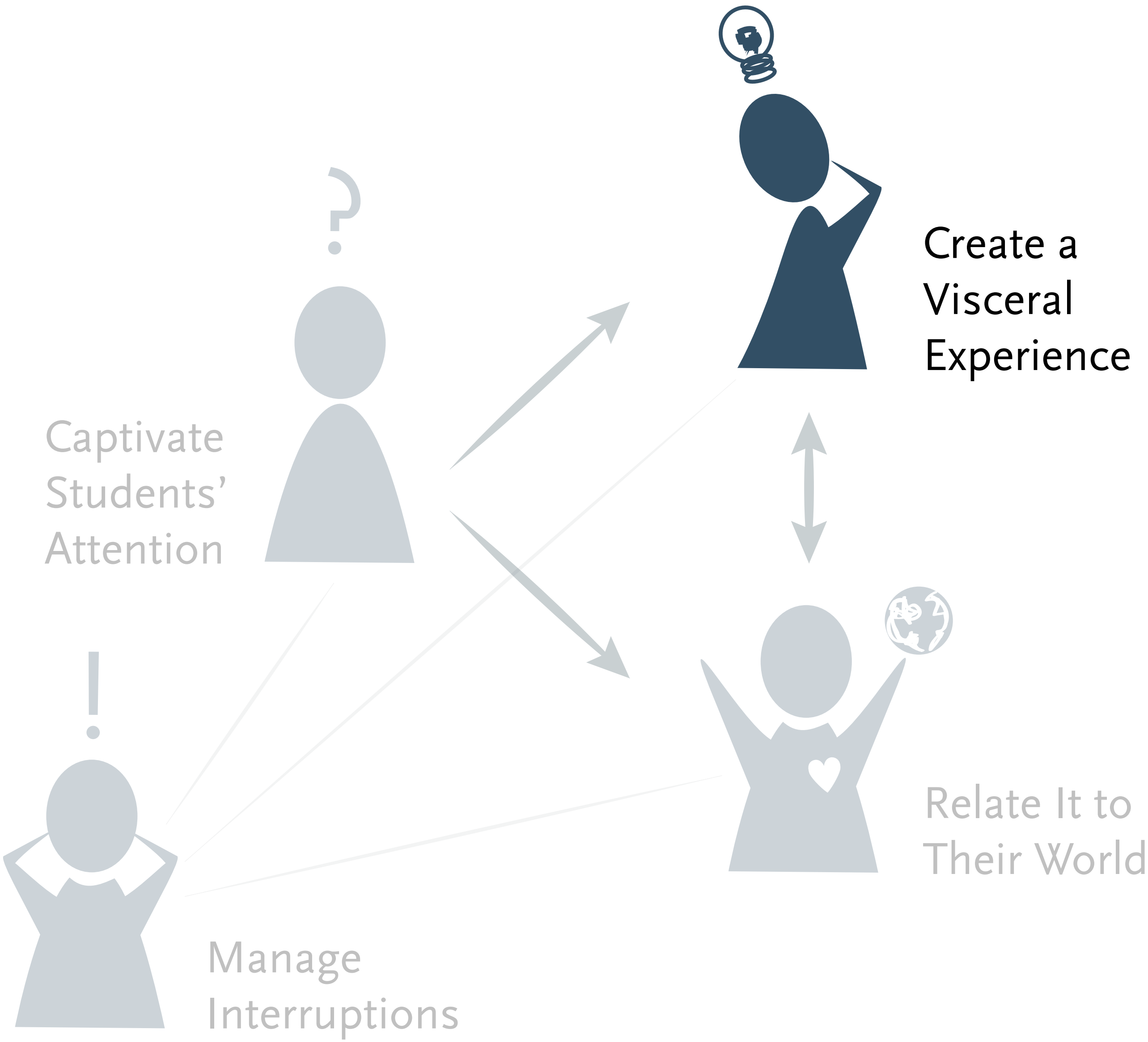
Several noticeable breakdowns were observed in the process of browsing content (see the artifact and sequence models in Appendix A). First, the amount of information provided sometimes mismatched the curiosity of the user: one student watched a live feed from NASA TV, but expressed disappointment that he couldn't read anything more about it. Second, users lost interest when content lacked hierarchical structure.

We also observed that participants imposed a perceived structure even when reading long passages of text. For example, another student we observed talked aloud about her process of reading text-intensive content that lacks hierarchy. She read the first sentence of each paragraph in order to quickly understand the content and determine whether she wanted to read any further. Hierarchical representation of digital content is strong in a sense that it implicitly provides users the freedom of managing information intake.

In addition to enhancing browsability, hierarchy also increases user engagement. Presenting information in layers, with actionable items and the "pitch" at the forefront, and the opportunity to delve into details below is a tactic used by web experts in industry (Porter). This method allows the content to be versatile for potential consumers who have different levels of motivation for learning about a service. Just as industry experts use hierarchy for increasing user participation, or "social traction," this strategy can be used to make content versatile for an audience as diverse as students.

Recommendation

Provide clear hierarchy and let students control information intake.


Create a Visceral Experience
Captivate Students' Attention
Relate It to Their World
Manage Interruptions

Create a Visceral Experience

Emphasize both the technical and viscerally emotional qualities of the activities on the ISS, and consider hands-on approaches to content presentation to appeal to students.

"We had a major failure of the Russian computing systems on the ISS... we were losing battery power to the Soyuz. If we didn't have a solution in eight hours, we'd have to abandon the space station... If we were to undock, we wouldn't be able to control [the station's altitude] and the space station [...] might have been lost."

– James, test coordinator and flight controller

Stories like James's show that the ISS is about emotionally charged stories of risk and adversity just as much as it is about technical engineering challenges; both of these qualities appeal to students. Therefore, the second section of our educational model focuses on the types of content that students find interesting as well as the best methods to present it to them, mixing a visceral and emotionally appealing approach with technical content that will deepen students' knowledge of science and space.

We identified two driving qualities of the interesting activities mentioned by flight controllers and students: emotional and technical. Some stories about the ISS, like James's, are extremely visceral, while other information is dry and technical (e.g., general details of how things work). Some students are interested in highly technical information, while others are intrigued by the more emotional aspects of the ISS.

Interviews with educators also revealed that certain educational techniques are extremely powerful despite the diversity of students and content types. Namely, hands-on and interactive teaching methods provided almost universal success and popularity amongst the students that we observed. This focus on interactivity could provide the backbone of our educational methodology.

Findings

1. Hands-on presentation of information stands out as an educational tool.
2. Science experiments onboard the ISS intrigue students and flight controllers.
3. Students want to know about both technical details and experiential elements of life in space.
4. Emotion adds excitement and increases memorability.
5. High risk and critical activities are most interesting.

Eager to learn about a new concept, Ms. Gomez's students await the outcome of their experiment.

Create a Visceral Experience

1. *Hands-on presentation of information stands out as an educational tool.*

Both teachers and students extolled the virtues of hands-on learning. When we asked high school students about their favorite classes, their favorites often involved a hands-on component. For example, Alexis beamed about her chemistry class:

> *"We all look forward to this class all day... it's hands-on, not like math, which is just a bunch of problems."*

– Alexis, eleventh grader

Additionally, our competitive analysis revealed that the hands-on and interactive nature of programs like Star Walk are incredibly appealing and differentiating, and students love hands-on ideas like the ability to track the ISS relative to where they are.

Every single teacher we talked to praised the utility of such activities as an educational tool. Hands-on exercises were commonly used to engage students: we observed students take pride in building molecules using marshmallows, and an astronomy teacher even took her class outside to see the ISS.

Recommendation
Present content in a hands-on manner.

An astronaut conducts a science experiment onboard the ISS. We found that these experiments are extremely interesting to a wide variety of people.

Create a Visceral Experience

2. *Science experiments onboard the ISS intrigue students and flight controllers.*

Five out of ten flight controllers we interviewed named science experiments as one of the most interesting activities taking place on the ISS. For example, a flight controller told us excitedly about how the crew brought common flies to the ISS to observe their reactions to low gravity, and discovered that over time the flies realized they no longer needed to use their wings and just "kicked off" from various surfaces.

Meanwhile, one of the biggest takeaways from our student interviews was the surprising interest they showed in these experiments when we introduced them. Card-sorting activities revealed that more than half of the students found science experiments on the ISS interesting. More knowledgeable students even named the subject as something they'd like to know about without us even mentioning it (like Ashwin, a high school student who immediately claimed that he "would really want to know more about the experiments" when asked what he would most like to know about the ISS).

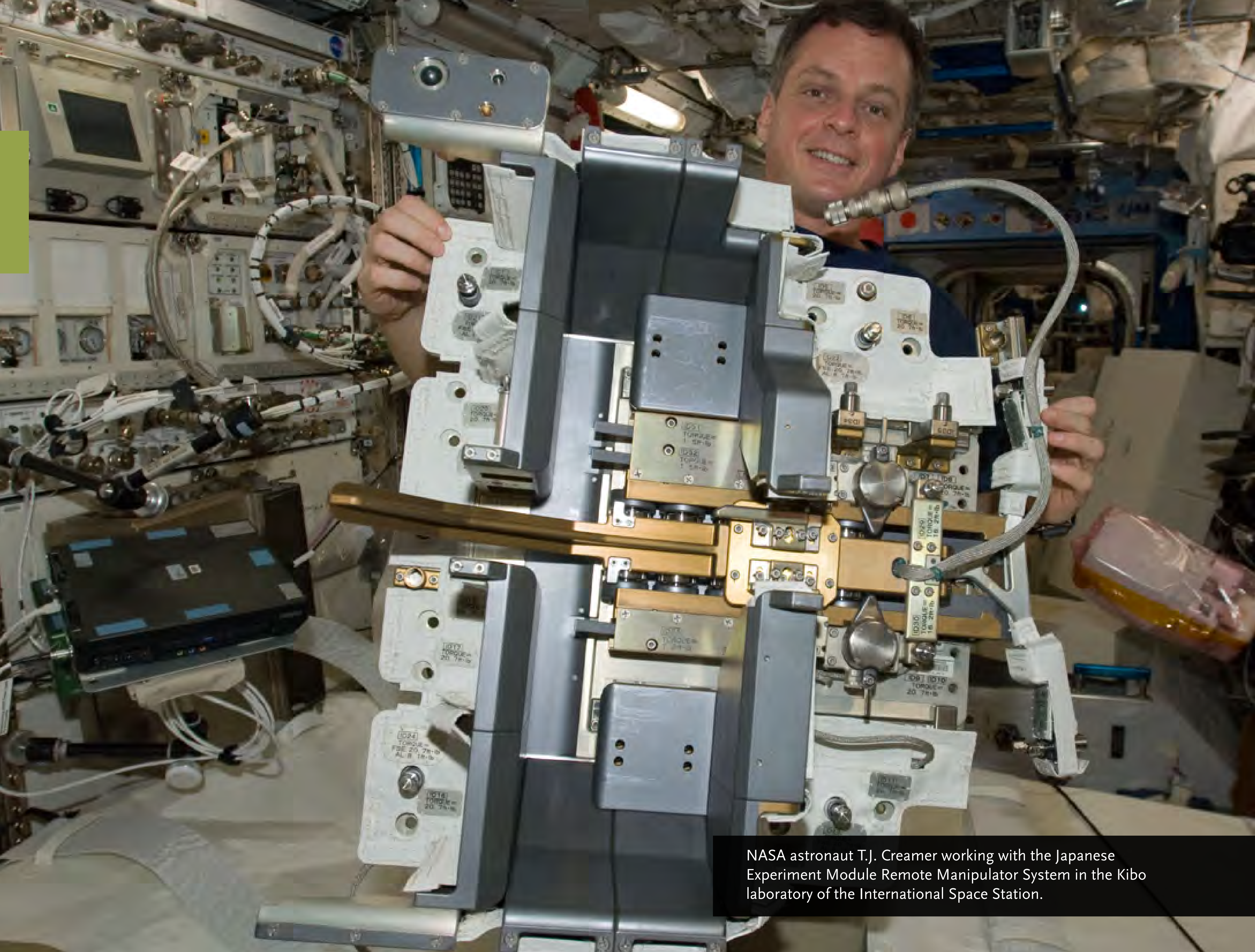
Scientific experiments serve a great educational purpose and may even instill a greater fascination in science with students, but as one flight controller pointed out, they are also crucial in communicating the significance of the ISS project and NASA in general:

"I think if people really understood the impact worldwide that NASA experiments have had, they would be much more likely to support NASA, and that goes back to our government supporting us too."

– Lauren, Flight Activity Officer

Recommendation

Highlight and explain the rationale behind science experiments onboard the ISS.



NASA astronaut T.J. Creamer working with the Japanese Experiment Module Remote Manipulator System in the Kibo laboratory of the International Space Station.

3. *Students want to know about both technical details and experiential elements of life in space.*

As discussed earlier, students have incredibly diverse interests. However, we saw that technical and experiential material kept resurfacing as appealing content.

Some students are very curious about the technical "how?" aspects of the ISS: for example, one student asked aloud, "So how do astronauts get from the shuttle to the station, anyway?" while Till and Ryan (two high school students) actually flagged us down to ask us about the station's orbit.

Other students were not so interested in the technical details; "I think it's cool, but I wouldn't want to read about it," stated one student about the powering of the ISS. Despite the mixed reactions, though, there was a strong enough curiosity about technical material to warrant the ability for students to potentially delve in and learn about how things work using ISS *Live!*

On the other hand, many students expressed curiosity over the experiential aspects of space. One student wondered if the typical task of opening a jar is any different, while another expressed interest in "zero-gravity exercise." Five students wondered what it was like to float around in space. Low gravity opens up a world of questions, and allows students to openly question what would differ from their gravity-laden experiences.

Recommendation
Provide opportunities for students to learn about the experiential and technical aspects behind the ISS.

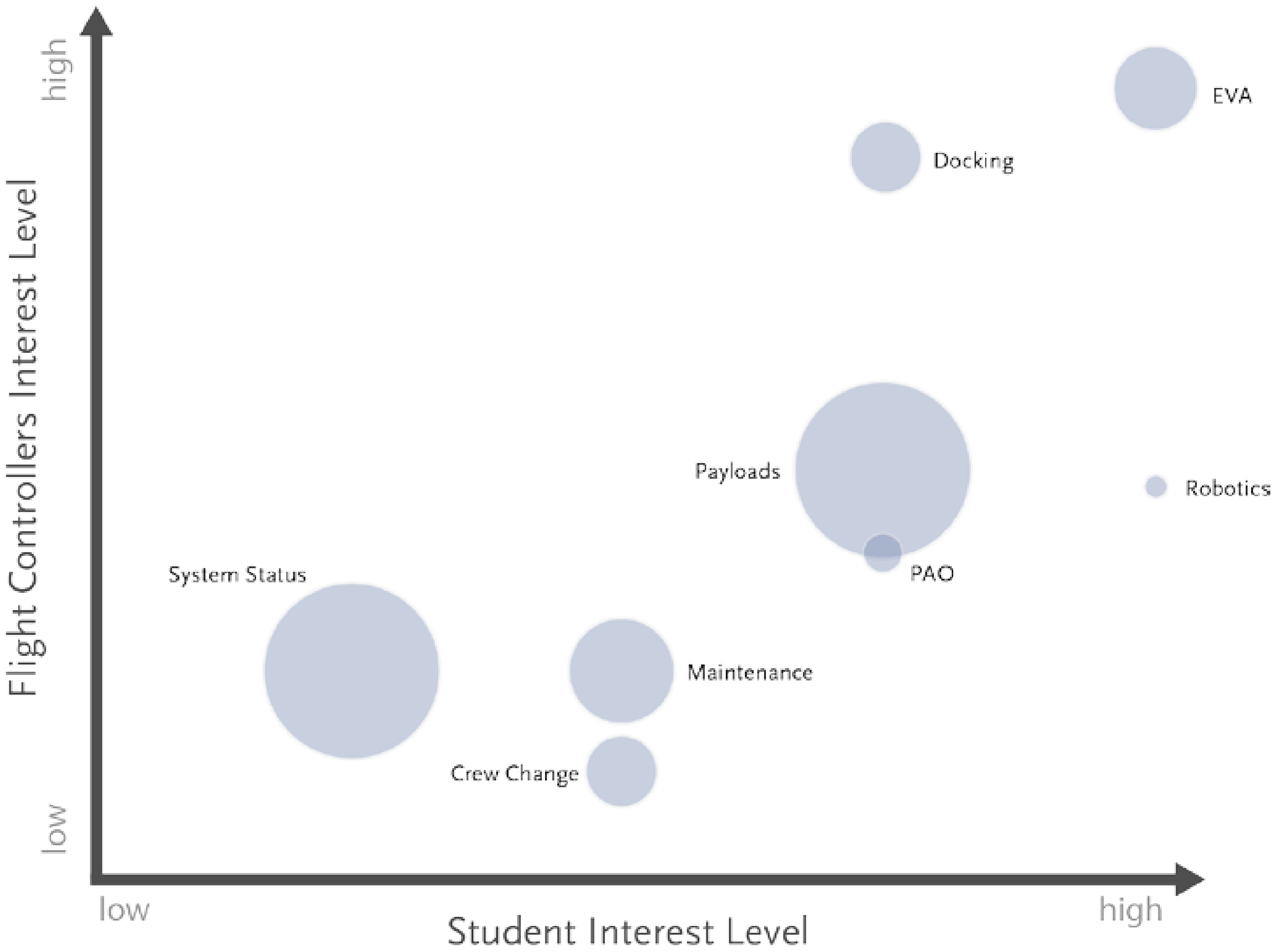
Flight controllers often cited activities like EVAs and other high risk activities as giving them a strong emotional feeling during our talks with them.

4. Emotion adds excitement and increases memorability.

Emotional stories about the ISS are abundant and can transform dry, technical information into visceral stories that engender passion and interest. For example, an activity about repair of computer systems can sound boring to a high school student, but James's story (p. 48) spins it into one that includes the potential risk of failure and possible abandonment of the ISS. This engages an audience far more, making even the driest scientific content exciting.

Moreover, our literature review revealed studies that have shown that emotional salience aids memory and improves learning capability (Mentis). In other words, providing the emotional stories behind some of the activities onboard the ISS actually makes it more memorable to students, making it more likely that they'll absorb what they have learned.

Recommendation
Highlight any emotional aspects of ISS activities through stories.



(size of point indicates the frequency of an activity, larger points occur more often)

5. High risk and critical activities are most interesting.

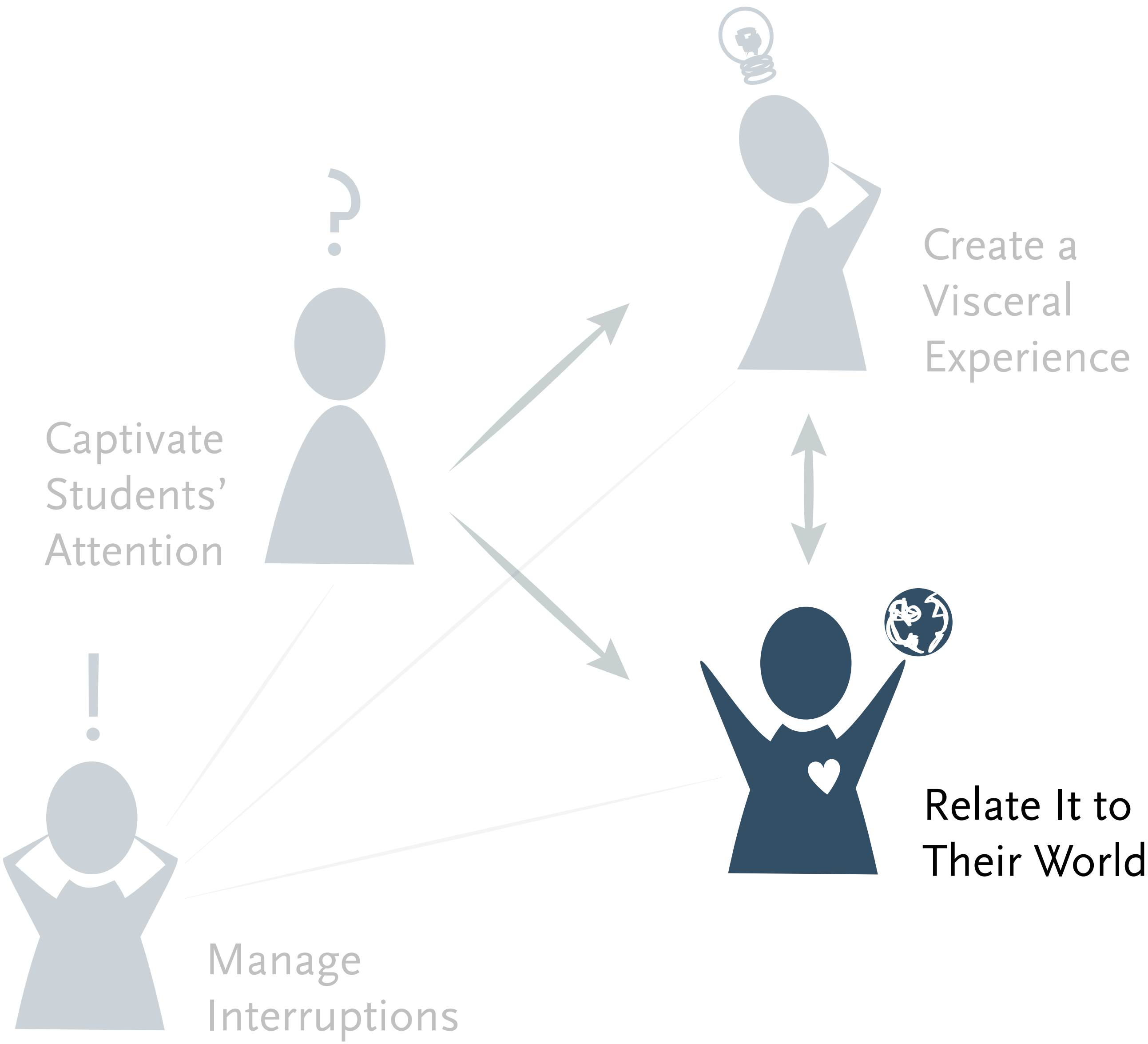
Eight out of ten flight controllers identified high-risk activities as incredibly interesting. For example, one flight controller laughed that extra-vehicular activities (EVAs) are cool because "there's nothing between you and death." Meanwhile, when we asked Leah, a power resource officer, about the most memorable and amazing highlights of her time at NASA, she responded quickly by telling us about an extremely critical failure of the cooling systems onboard the ISS:

> *"The cooling systems... aren't redundant at all. If it fails, you have to power down half the station... We had one fail last summer. We usually just restart it and it comes back, but we couldn't get it restarted and spent all day over three weeks trying to figure out how to get it back. We had the crew do EVAs they were untrained for... we were one-fault tolerance: if anything else happened, the station would have to be shut down completely."*
>
> – Leah, Power Resource Officer (PRO)

Stories involving this much criticality are thankfully infrequent, but smaller degrees of risk (e.g. the kind found in an EVA) are also common factors of exciting activities. We found that students often share this interest, expressing interest in activities they perceived to be critically important. "Repairs seem interesting, [since] things can go wrong really fast," one student stated; this sentiment was a common theme.

Criticality, in these situations, adds a sense of thrill while educating students on the real risk behind seemingly simple operations. Part of the appeal of space is its dangerous nature, and communicating this aspect makes the content both more enthralling and more educational.

Recommendation
Educate students about the real risk behind ISS activities.


Create a Visceral Experience
Captivate Students' Attention
Relate It to Their World
Manage Interruptions

Relate It to Their World

Highlight relevance by connecting the information to the world around them, relating it to what they already know, and providing a purpose to why they are learning about these topics.

"I also like the fact that like that science is kind of inter-related. So science is... kind of like a quantitative and qualitative evaluation of everything. I think that's just really cool."

– Isaac, twelfth grader

Like Isaac, students enjoy learning about areas that relate to their lives and serve a clear purpose. What drew Isaac to science was that it explained the world around him and provided answers to his questions. He explained how the sciences seem so inter-related since they all build on each other and help dissect a topic in a different way, whether he was learning about amino acids or gravitational force. Other high school students, college freshmen, teachers, and flight controllers also expressed that they enjoy learning about areas that build on their prior knowledge, unveiling new insights that are interesting and beneficial to know. Through literature, we've learned that a good way to cement the information that the student is learning is to simply connect it to the students and provide purpose and relevance to why they are learning about these topics. The student will find more enjoyment when they can draw parallels to their past classes and what they have learned before (Hein). By drawing connections to students and building off of their prior knowledge, students will find value in what they learn. Mr. Williams, for example, stressed the importance of connecting concepts to students' lives to get them more interested in science: "Just kind of keep their interest, tie in things all around them with astronomy and hopefully make them more interested in science in general."

Findings

1. Familiarity facilitates interest.
2. Students want to see value in what they learn.
3. Different perspectives enrich the story.
4. Camaraderie resonates with students and flight controllers.

While giving us a tour of his high school, Isaiah highlighted how students are excited to work on projects that relate to their daily lives.

1. *Familiarity facilitates interest.*

It is easier to learn about new concepts when it builds upon prior knowledge. However, since individuals don't enter situations expecting to use what they already know, it is important that the application activate this prior knowledge so they can build on it productively. Even the smallest instructional intervention or reminder can trigger this knowledge and spark their memory in a certain area, but it is critical that the correct and appropriate prior knowledge is activated, otherwise the student may not build the proper understanding.

Although students are unaware of this process, they expressed enjoyment in learning about subject areas in which they had more past experience. One student boasted, "I kind of remember that from class!" and immediately got excited, trying to name the planets. This excitement is not unusual; students feel a sense of accomplishment when they encounter material that is not overwhelmingly new. They want to learn more, but they feel more comfortable when it is in a familiar area.

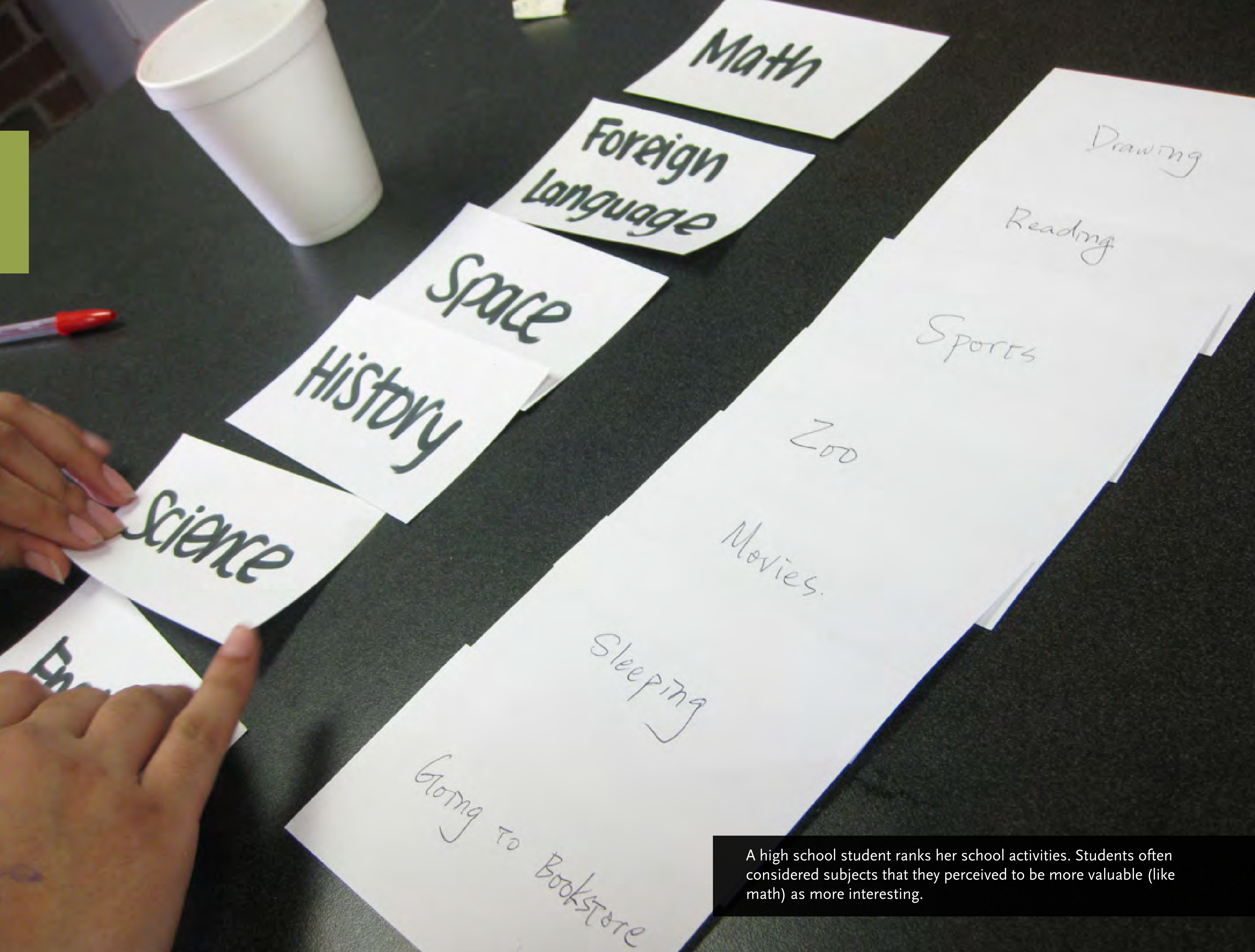
When participants searched for articles and sites, all of them started by searching for keywords that related to something they had either learned about themselves or had heard about through friends. One college freshman searched for a site about neuroscience because his best friend was interested in the area and he had been hearing more about it in the news:

"I remembered one of my best friends was a neuroscientist, so let's see what's in neuroscience ... Looks like an aggregator website, so maybe I can check out their featured article... Oh, stem cells! Lots of this seems like it's going over my head, but I've heard about stem cells in the news, so let's check that out. Oh yeah, I've heard that stem cells can help disease research!"

– Sohail, electrical-computer engineering freshman

Despite reading about information that was past his level of understanding, he continued to read due his connection and brief familiarity with the subject area.

Recommendation
Connect to prior knowledge when teaching new topics.



A high school student ranks her school activities. Students often considered subjects that they perceived to be more valuable (like math) as more interesting.

2. Students want to see value in what they learn.

When asked which activities they would like to improve on, many students ranked activities which they perceived valuable to their careers at the top. This suggests that students want to know that their learning serves a greater purpose and is applicable to the world around them. One of the high school students we talked to did not value history, and ended up placing it at the bottom of his list of what he wants to improve on because "history is nice to know but you can't really do anything with it, except teach history."

Without understanding the value in learning about something new, the educational experience feels like a "chore," as a couple of students had expressed. In contrast, when students understand the purpose of what they are learning, the knowledge motivates them to learn more. Because the teacher introduced why it is important to be skillful in math, for instance, the following student found that what he was learning was indeed going to be beneficial to him going forward. He spoke about how his teacher made math purposeful:

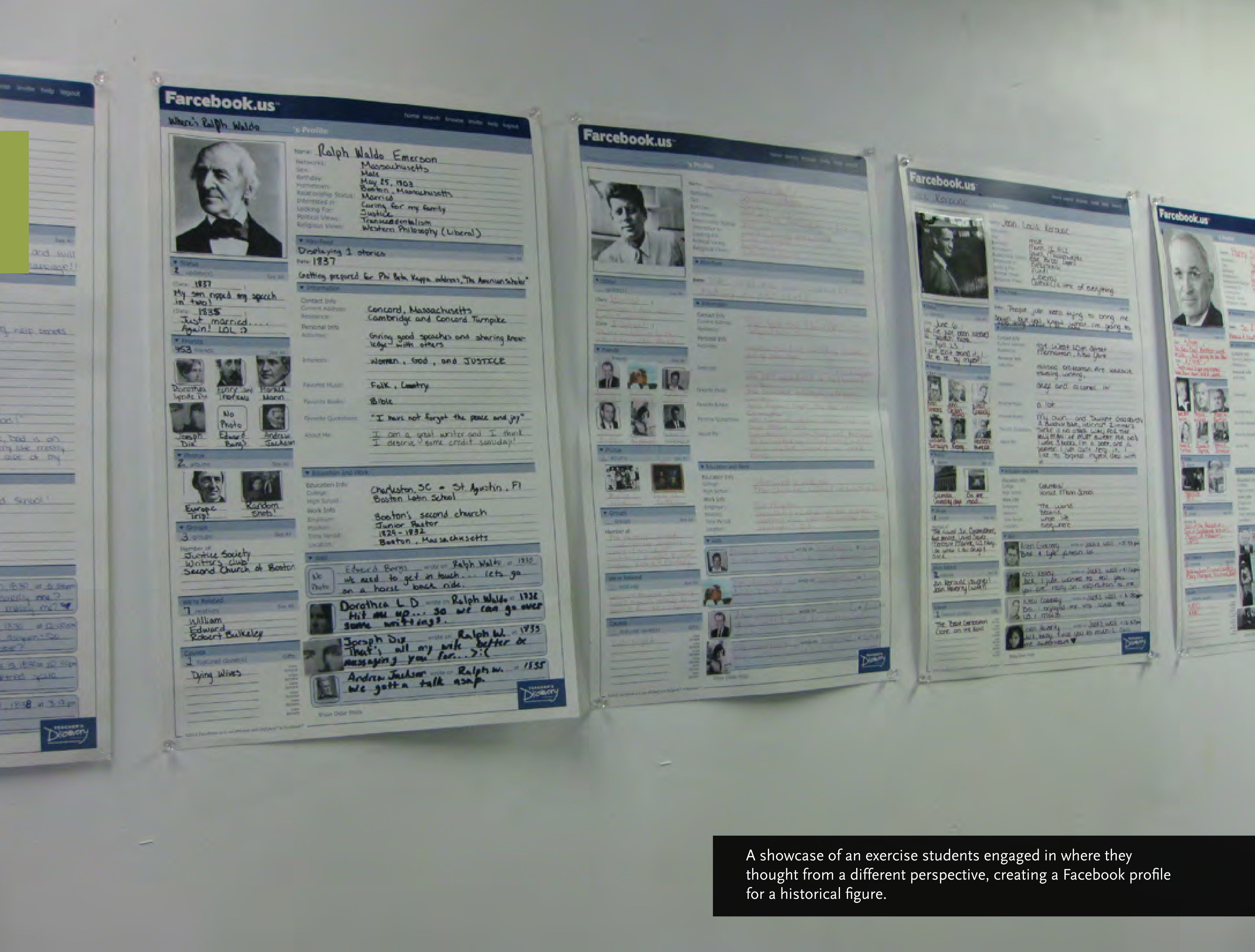
"He makes math seem like what it is, which is an essential thing in just human articulation of the world around us, and that there's a point to math."

– Isaac, twelfth grade student

This insight emphasizes the value of demonstrating the application of concepts and principles, because the sense of purpose makes the learning experience more meaningful.

Recommendation

Highlight the purpose of ISS activities and the real-world value of any educational material.



A showcase of an exercise students engaged in where they thought from a different perspective, creating a Facebook profile for a historical figure.

3. *Different perspectives enrich the story.*

According to the constructivist learning theory, offering students a different way of thinking about the same thing, and putting it in context of their own life strengthens their understanding of a topic.

If information is displayed appropriately, students will want to learn more about it even if they do not agree with or understand the perspective that is being presented. Coming from a variety of cultures and backgrounds, students are intrigued to learn more from the perspective of others who are not like themselves. A student from Germany enjoyed learning about US History "I can see all the history, like WWII from a different perspective." To walk in the shoes of another is daunting but interesting at the same time.

The flight controllers also felt that alternate perspectives help them better understand their job and the people they are working with. They enjoy learning about how the astronauts think to better understand their perspectives. One flight controller shared:

"I always wanted to be an astronaut so it's kind of fun to hear about their perspective on things and plus for planners, we're constantly scheduling their lives. But to actually hear feedback on how their overall experience is and their life is, it kind of puts a human touch back into the job. I enjoy that."

– Aaron, Operations Planner

Recommendation

Present a different perspective than what the student is used to.

At one high school we visited, each student traditionally paints their own locker; this group of seniors, however, decided to paint their lockers together to express their camaraderie.

4. Camaraderie resonates with students and flight controllers.

Flight controllers and students shared a sentiment for the spirit of teamwork that brings people together for a common goal.

We observed that social sentiments were major drivers behind student participation in their favorite activities. For instance, even though one student had miserable experiences of throwing up after track, he was inclined to continue with the sport because he loved the camaraderie.

When we inquired about their highlights at NASA, flight controllers expressed a sense of pride and fulfillment as they shared stories of international collaboration. For several, the experience of working on something that extended past the boundaries of their country felt honorable and "cool"—almost like being in the "intergalactic council from Star Trek" according to one team member. Another flight controller, Sarah recalled how meaningful it had been for her when her team had been able to help the Japanese mission control team during the recent earthquake disasters:

"Dealing with all the different cultures and integrating one giant program over all these countries that have different priorities and ways of working... we heard our Japanese counterpart say, 'we've had an earthquake.' They left the building and we stayed on to monitor... that was nice to feel like you could help out in a small way."

– Sarah, Integrated Systems Engineer

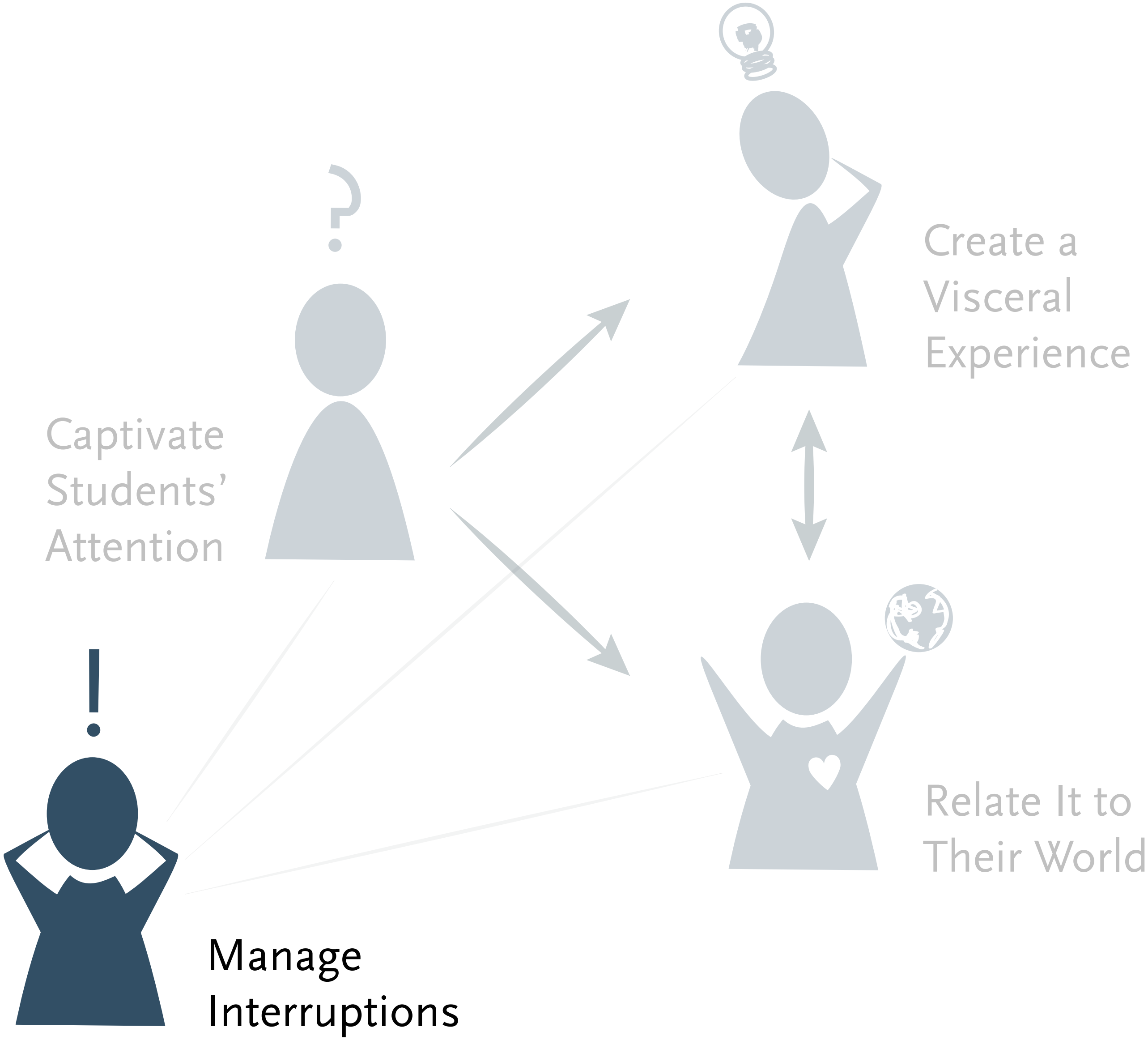
These stories showcase an incredibly human aspect of their work, that is often missed by the public.

Close collaboration between nations that have been working for years to achieve a common goal of human spaceflight is extremely exciting, and is an achievement that students recognize and appreciate. The fact that a multitude of countries are able to overcome cultural differences and unite for the space station can be summed up in one high school student's words who thinks "it's cool that [nations] can look past politics to work together."

By bringing some of these stories out to the public, students can relate to flight controllers in their fondness for the team spirit.

Recommendation

Highlight international collaboration onboard the ISS.


Create a Visceral Experience
Captivate Students' Attention
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Manage Interruptions

Manage Interruptions

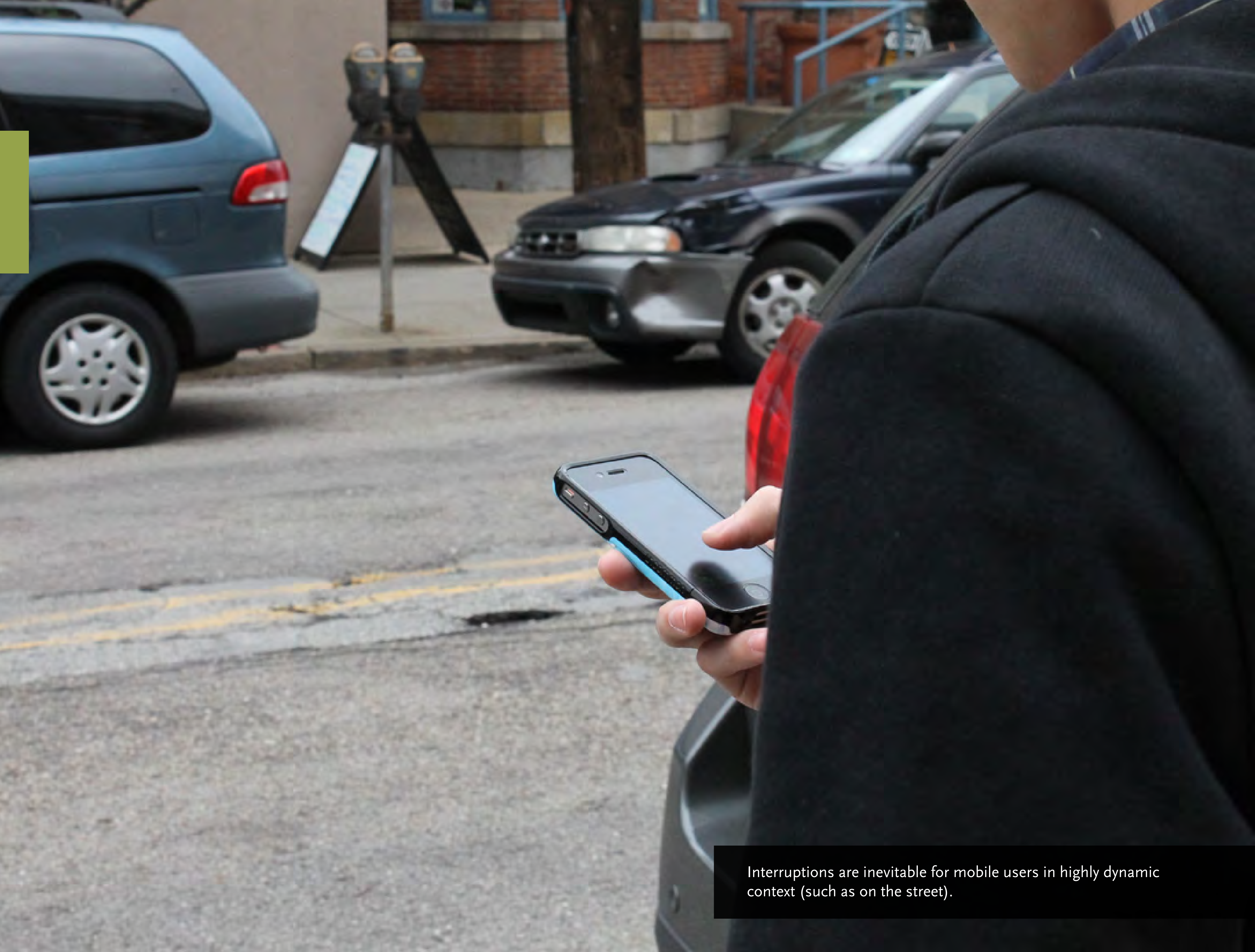
Create an interaction that allows students to control their involvement by allowing them to easily get to the task at hand and minimizing disruptions to the workflow of interest.

Mr. Fowler, a high school teacher, is a guru when it comes to handling disruptions in class. He revealed that the method he used to accommodate disruptive students is to mix them with academically active students to generate positive peer influence. This highlighted the fact that students are influenced by their surroundings and the environment they are in. Two other teachers we observed had a somewhat different approach. When disruptive students say something in class, other students often start to make comments adding on to it. The teachers then join the conversation entertain the crowd for little while, but skillfully bring the class back into focus.

This concept of disruption also occurs in the context of user interaction with digital content. Through observations conducted on students, we identified two main types of disruption. First, the situations where participants lose attention on the current content and exit. Second, the disruption of users' attention flow caused by the imbalance of user's expectation and system response. These disruptions are important aspects to consider in order to empower users to overcome these barriers that will hinder the interaction. From our literature reviews and field research, we consolidated insights on how modern interfaces addresses to the problem of disruptions.

Findings

1. Adapting to the environment reduces impact of disruption.
2. Immediate engagement with minimal disruptions keeps users interested.
3. People in control of their experiences are more likely to stay engaged.



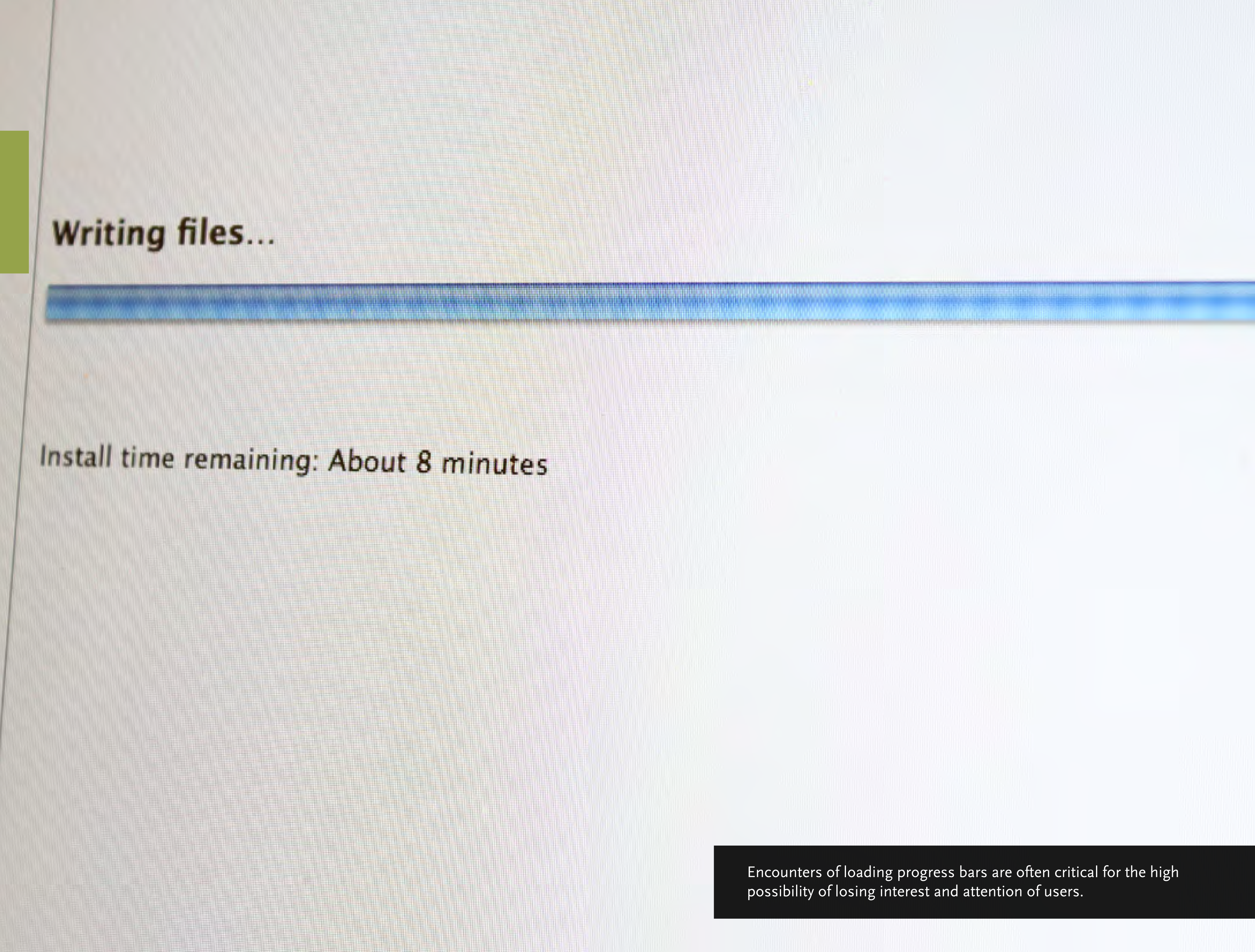
Interruptions are inevitable for mobile users in highly dynamic context (such as on the street).

1. Adapting to the environment reduces impact of disruption.

Designing for interruptibility is considered an important factor to consider when designing mobile applications, since disruptions to a person's flow of use occur extremely often in a mobile context.

This is also extremely important when designing for audiences with low attention spans. One literature source explained that the main success factor of Sesame Street is that the program was designed so that children can tune in and out without trouble. In conclusion, we see a need for applications to consider handling interruptions by providing an easy way for users to resume their use. (For example, one mobile design recommendation states that the application should take you to the main page of interest instead of the menu, allowing the users to jump back in quickly.) This is crucial in dealing with the loss of attention caused by various disruptions.

Recommendation
Allow the users to flexibly enter and exit the application.



Encounters of loading progress bars are often critical for the high possibility of losing interest and attention of users.

Manage Interruptions

2. Immediate engagement with minimal disruptions keeps users interested.

We observed that students are incredibly unlikely to wait for long loading times. Amir, a student participant in our research, started conducting other tasks on his smartphone while waiting for an application to download. Vivian, another participant, gave up waiting for NASA TV to load while exploring the NASA application on the iPad, and two out of three other participants also demonstrated identical behavior. In general, students tend to react to this disruption by multi-tasking or switching their attention to other tasks. In short, applications that do not factor this into consideration will risk losing users' attention.

Students are likely to lose interest if content takes too long to load. From our observations and literature, we have learned that the need for capturing students' attention in a short amount of time is crucial; more than 10-15 seconds of loading time is considered extremely poor response time (Hudson). During our observations of college freshmen exploring digital content, we noticed students leaving an application when it took too long to load.

If the interface interrupts the user in a way, they might simply retreat. For example, after Vivian left a web page with a lot of dynamic ads, she stated that she "would keep reading if it is well organized, without those flashing advertisements bugging my eyes." This illustrates the consequence of having elements that disrupting a user's focus on the current task and the importance of minimizing unintentionally annoying content.

Recommendation

Minimize interruptions to workflow and user goals.

Games are examples of applications giving high user control in order to make them stay engaged.

3. *People in control of their experiences are more likely to stay engaged.*

The importance of enabling user control is coherent with the concept of agency, which states that when an environment seems real, people tend to desire more control of action. Thus, the more immersive the environment, the more active one would want to be within it. When the things people do bring tangible results, they experience one of the characteristic delights of electronic environment: a sense of agency. As stated in Janet Murray's *Hamlet on the Holodeck*, "the ability to move through virtual landscapes can be pleasurable in itself, independent of the content of the spaces." Thus, rather than focusing on the quantity of interactions, emphasis should be placed on how to enforce a sense of participation and agency.

This is especially true in applications that requires intense user attention, such as games. Most technology-based games demand full attention from the user, but they have tactics for handling discontinuity. Several game design patterns seen nowadays give possible ways to handle this, such as the "pause/resume" feature that has become ubiquitous in games. In conclusion, allowing users to easily control their interaction and learning flow is crucial in dealing with the loss of attention caused by various disruptions.

Recommendation
Put users in control in the process of interaction.

Design Recommendations

Captivate Students' Attention

Curiosity arises from familiar topics with a new twist.
Invoke curiosity with a familiar, but thought-provoking, topic.

Students have diverse interests.
Offer a breadth of content and cater to the diversity of knowledge and interest levels.

Visuals universally attract attention.
Utilize imagery and visuals to make content appealing to students at first glance.

Hierarchy of information facilitates browsing.
Provide clear hierarchy and let students control information intake.

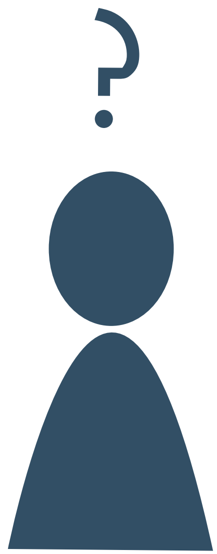
Relate It to Their World

Familiarity facilitates interest.
Connect to prior knowledge when teaching new topics.

Students want to see value in what they learn.
Highlight the purpose of ISS activities and real-world value of any educational material.

Different perspectives enrich the story.
Present a different perspective than what the student is used to.

Camaraderie resonates with students and flight controllers.
Highlight international collaboration onboard the ISS.



Create a Visceral Experience

Hands-on presentation of information stands out as an educational tool.
Present content in a hands-on manner.

Science experiments onboard the ISS intrigue students and flight controllers.
Highlight and explain the rationale behind science experiments onboard the ISS.

Students want to know about both technical details and experiential elements of life in space.
Provide opportunities to learn about experiential and technical aspects behind the ISS.

Emotion adds excitement and increases memorability.
Highlight emotional aspects of ISS activities through stories.

High risk and critical activities are most interesting.
Educate students about the real risk behind ISS activities.

Managing Interruption

Adapting to the environment reduces impact of disruption.
Allow the users to flexibly enter and exit the application.

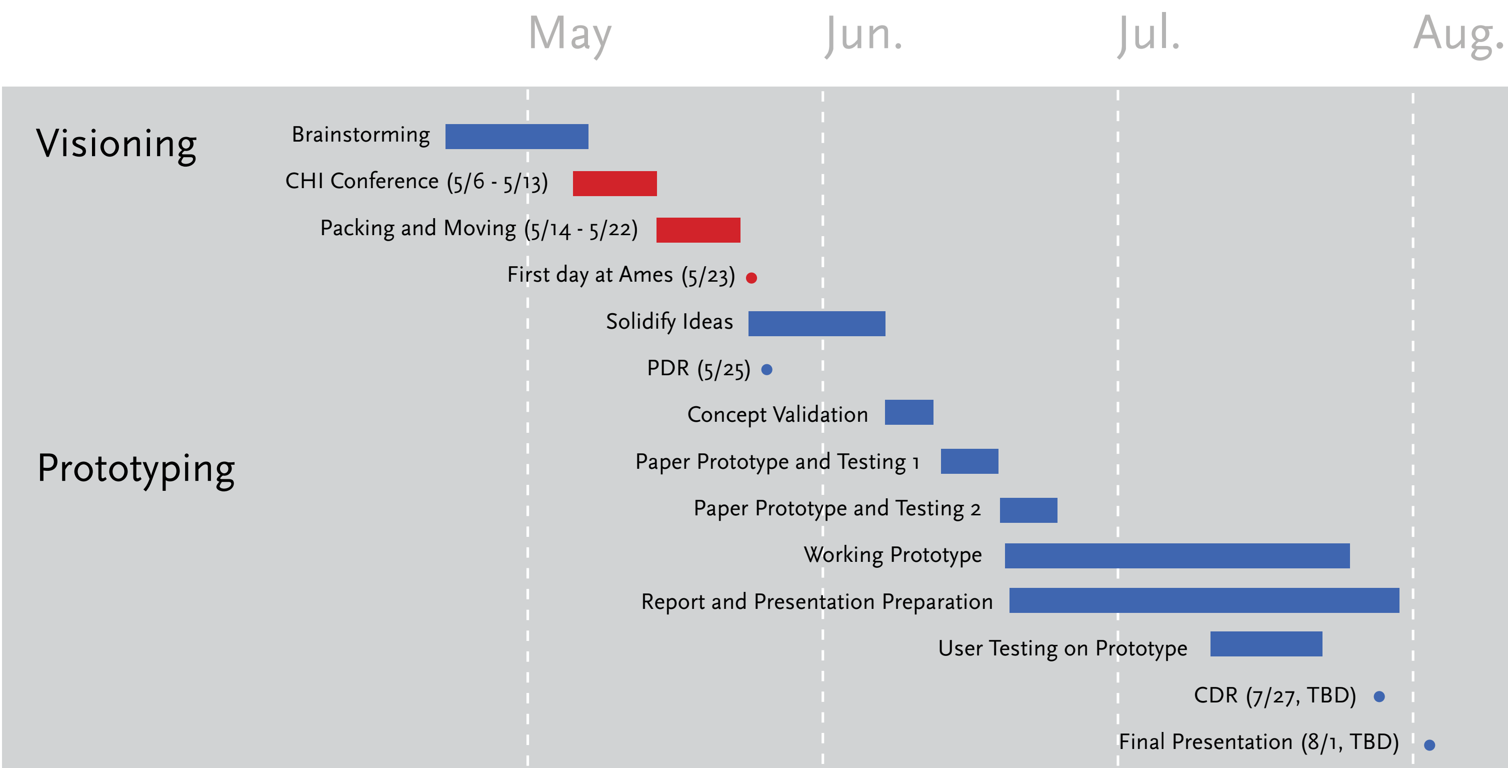
Immediate engagement with minimal disruptions keeps users interested.
Minimize interruptions to workflow and user goals.

People in control of their experiences are more likely to stay engaged.
Put users in control in the process of interaction.

Vision

Next Steps

Summer Schedule



Next Steps

Over the summer, we will be solidifying our design ideas, generate prototypes for iterations, deliver a full-functioning prototype by the end of summer.

At this point, we have concluded our research and synthesis phases. We visited four Pittsburgh schools, including four teachers and 19 high school students. In addition, we have conducted contextual inquiries on four college freshmen, activities with 10 flight controllers, and interviews with five space enthusiasts. Grounded in the insights from our synthesis phase, we have identified key insights to help us identify opportunity spaces as we move into the visioning phase.

Next we will conduct grounded brainstorming by performing various activities as a group. These activities include brainwalking, where each person starts an idea that gets passed off to the next person who adds to an idea to build off of each other's idea and generate a wide variety of concepts. We will then take these ideas and create wireframes and storyboards, which we will continue to refine and regenerate throughout this process. Through paper prototyping, we will conduct user tests to ensure our design solution is robust and usable.

While crafting personas, our team examined detailed data from each student that we interviewed and mapped them to persona archetypes.

Personas

Our team constructed three different personas to represent the wide variety of students that we encountered during our research phase.

Personas are fictional characters that represent the different target users encountered during user research. They are synthesized from data collected about the target users' daily behavior patterns, goals, skills, attitudes, and environment, and include fictional personal details to ensure that the persona is a realistic character. In doing so, personas add a personal touch to data that makes it easier and empathize with, while providing a unified team understanding of the target audience that helps to identify key requirements as teams delve further into the development and design process.

We mapped all of our research participants to three different personas: Faith Hudson, Steve Brown, and Taylor Jordan. Faith is our primary persona in that most of what we design will be directed primarily towards her, while Steve and Taylor provide the role of "secondary personas" (whose needs can also be fulfilled through the product).


THE COMMON APPLICATION
Legal Name
Preferred name, if not first name (choose only one)
Birth Date
Preferred Telephone ○ Home ○ Cell
E-mail Address
Permanent home address
If different from above, please give your current mailing address


±5%
40

Faith Hudson

"Dad keeps bugging me to figure out what I want to study in college. I have no idea though! It's really stressful..."

Faith, a "B student" in the eleventh grade, has fond memories of building a model of the solar system in elementary school, but hasn't really learned much about space since then.

Nevertheless, she gets very interested when she does hear something about space that she relates to; her brother told her about Pluto's recent change in classification and she excitedly passed the news on to all of her friends.

Chemistry is Faith's favorite subject because of the hands-on experiments, and she really enjoys school when what she learns just "clicks together" for her (an experience that gives her a sense of confidence and pride). After school, she goes to the Boys and Girls Club, where she tutors 7–10 year olds and plays board games like Scrabble with her friends. Faith loves both activities because she often learns something new from them: teaching the younger children is an educational experience itself (and she's often amazed by how much the kids actually teach her), and even Scrabble and Apples to Apples present opportunities for her to learn new things while having fun.

However, Faith is applying for college next year and has no idea what she wants to study or do for a living. Her parents and school advisor have recently been pressuring her to start thinking about it, but she feels stressed and lost without direction.

Goals

- Figure out what she is most interested in and determine a possible career path.
- Learn new things.
- Keep coming up with interesting things to teach the kids at the Boys and Girls Club.
- Connect the material she learns, providing her with a sense of achievement and a deep understanding.


GRAND DESIGN
SPACE, TIME, and
Worlds


KINECT
ROCKBAND2
PlayStation2
singstar

Steve Brown

"Space is just really cool: black holes, antimatter, the existence of aliens and stuff… there's so many unanswered questions out there, so many more things for us to discover."

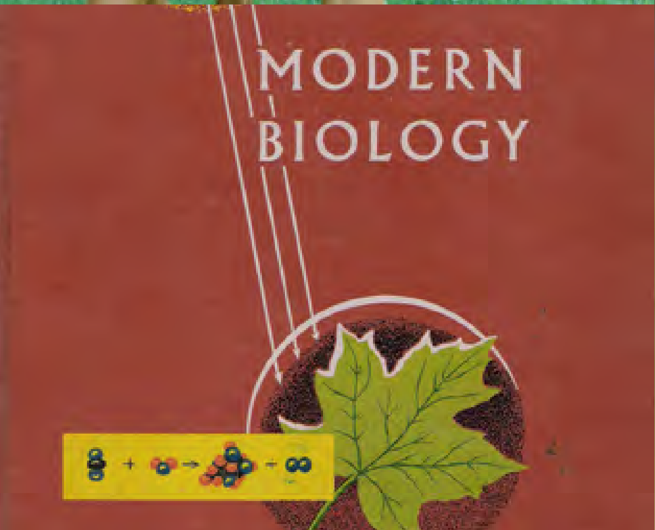
Steve is entering his freshman year of college at Caltech. He attended space camp when he was 12, and has been in love with space ever since.

Space appeals to him because of the big questions it raises: he's fascinated by theories of extraterrestrial life and the size of the universe. He developed an affinity for space books over the years, and Death by Black Hole inspired him so much that he even formed his high school's first space club. He has excelled in science and loves the subject, even winning a regional science fair during his senior year; however, he doesn't put much effort into his humanities classes and is particularly bored by history.

Physics is his favorite subject because of how it explains the world around him; however, Steve decided to study electrical engineering in college because it teaches him how everyday things work and gives him the opportunity to make things. Still, he hopes to double major in physics and join the astronomy club to accommodate his interest in space. Steve fills the rest of his free time by playing video games and basketball with his friends.

Goals

- Gain a deep understanding of how things work.
- Ponder the deep, philosophical questions behind the universe.
- Feel confident and knowledgeable around his new astronomy club friends.
- Perform well in his electrical engineering curriculum without sacrificing his space hobby.
- Enjoy college and make friends with similar interests.



MODERN
BIOLOGY


CENTENNIAL
4
16

Taylor Jordan

"Math is terrible; no matter how much I study, I still get bad grades. I like biology, though... I'm actually doing pretty well in it."

Taylor is a tenth grade student. Due to her struggles with math, she doesn't have much of an interest in math-heavy sciences but loves subjects that she performs well in.

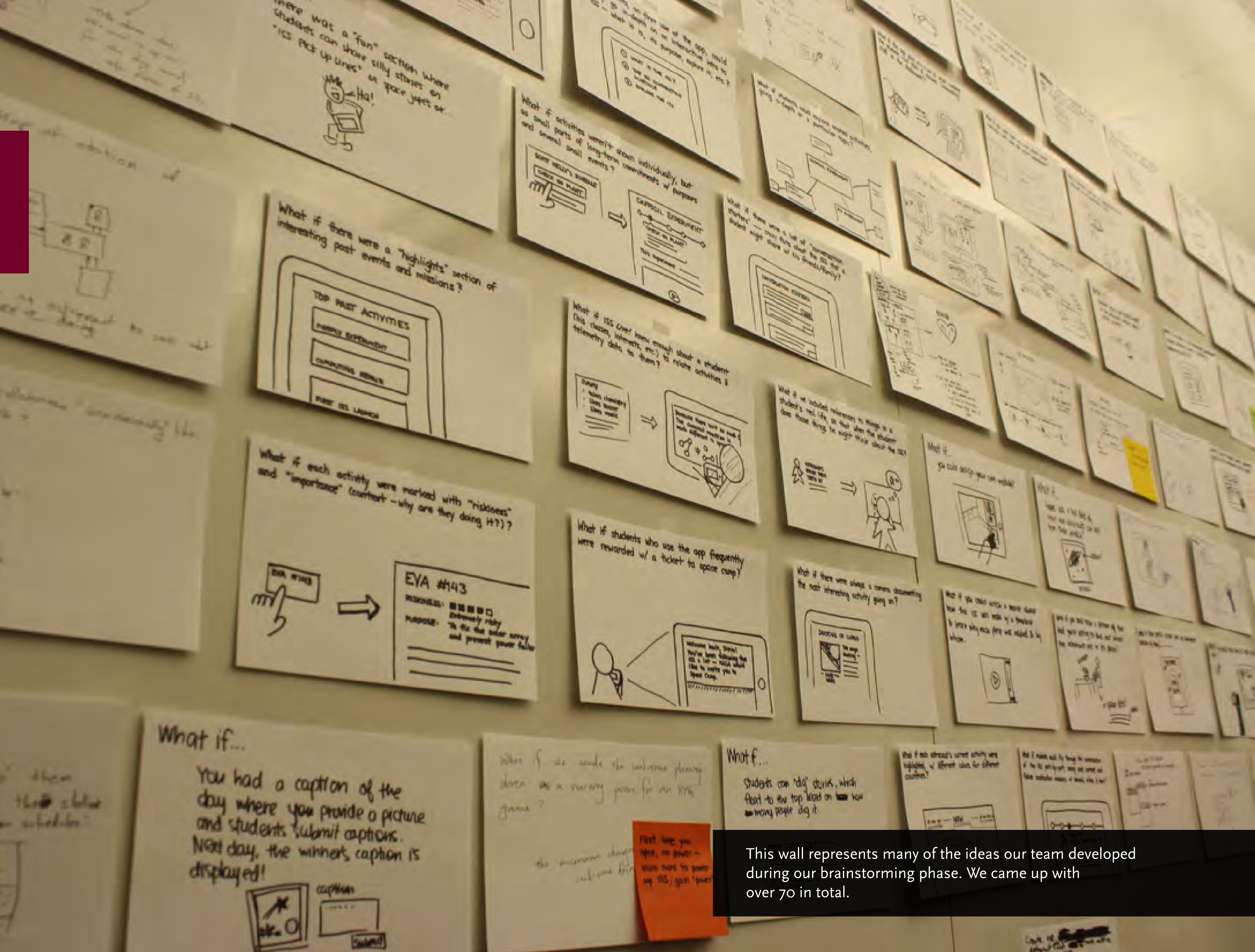
Math is a major bottleneck in her educational path; she's lost all her confidence in the subject over the years and never seems to do well even after spending hours and hours studying. Unfortunately, her growing resentment for the subject affects her attitude towards other math-related subjects as well (such as physics). Nevertheless, biology still sparks her interest; it doesn't involve math, it plays off of her love for animals, and (most importantly) she's good at it.

She works at McDonald's part-time to alleviate the financial burden of her family and often has to help take care of her younger siblings. In general, the pressure and time she puts into her family has always hindered her academic performance; for Taylor, school and education have never been top priorities.

Outside of her academic life, though, Taylor loves playing soccer. She's played on various teams since she was young, and loves the camaraderie of the varsity team at her high school; her passion for soccer stems from this value of collaboration and teamwork. She loves her dog, and in her spare time enjoys playing with him in the park or hanging out with her soccer friends at the mall.

Goals

- Take time out of her busy schedule to play with her dog and hang out with her friends more often.
- Deepen her strong ties with her soccer team.
- Feel like she isn't struggling with her coursework and succeed in courses outside of biology.
- Establish an ability for employment after high school.



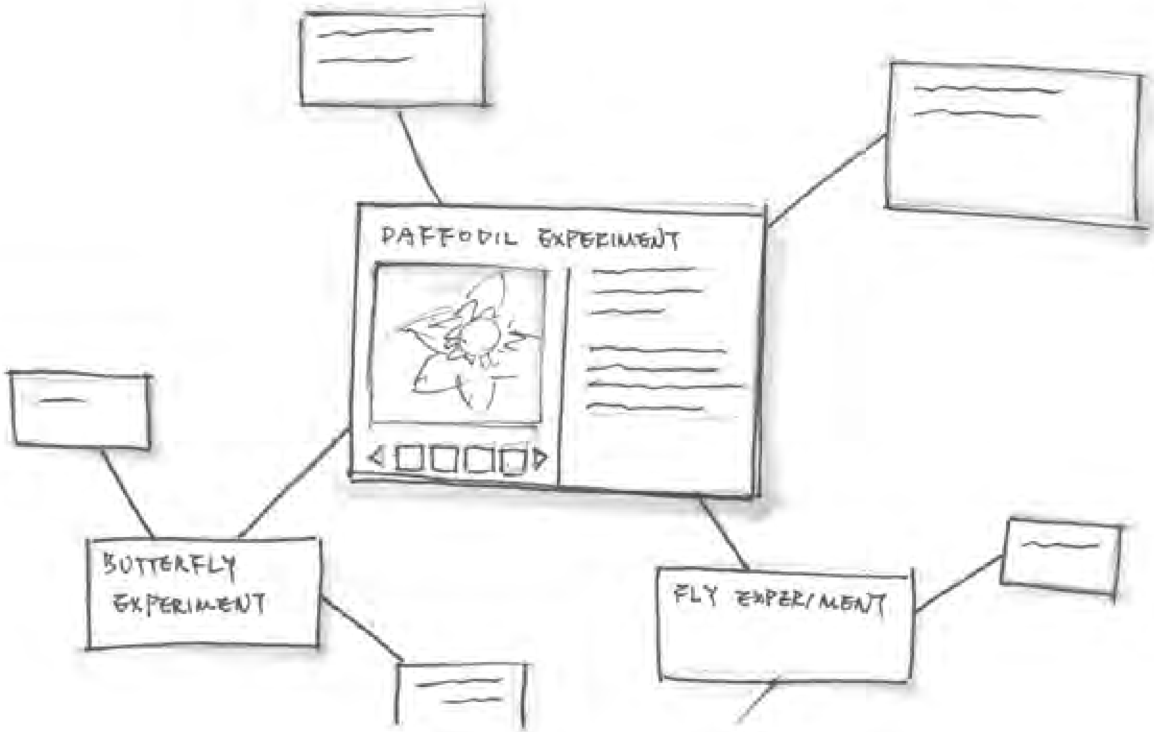
This wall represents many of the ideas our team developed during our brainstorming phase. We came up with over 70 in total.

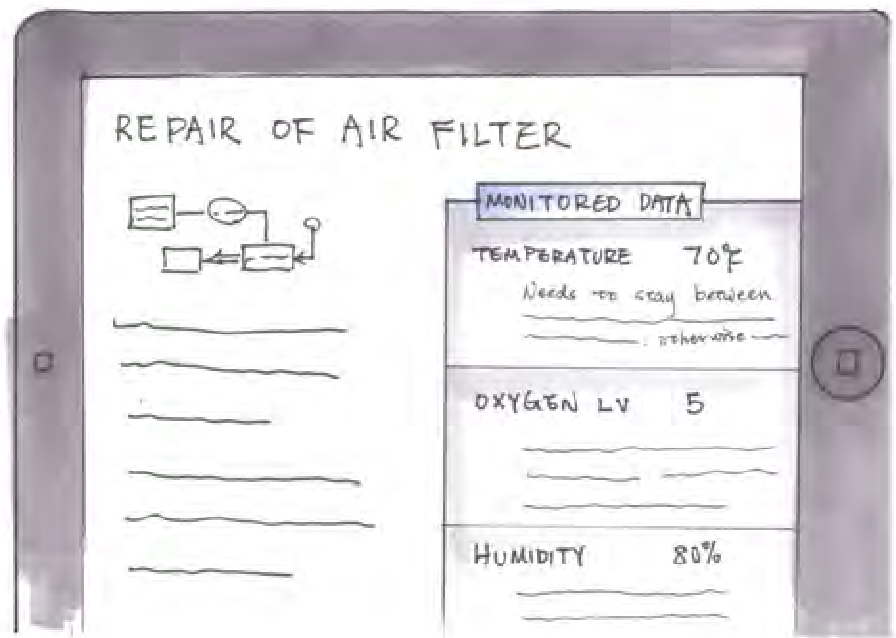
Concepts

Our team brainstormed over 70 ideas and organized these ideas into themes. These themes provide a rough idea of the directions our project can go.

The team revisited the user research data and findings before conducting rapid brainstorming to ensure our visions were grounded by the data we collected in our field research. When brainstorming ideas we came up with "What if..." scenarios that students would find interesting, educational, and fun. Over 70 ideas were generated, which are then used to develop possible design directions we can take over the summer.

The ideas we generated are very rough and should not be considered final by any means. We would like to use the following themes as conversation starters to generate more ideas: Personalized Dynamic Content, Immersive Virtual Experiences, and Communication Between Peers and NASA. Presenting personalized dynamic content can enhance the experience of the students by allowing them to explore areas which they find interesting while highlighting information that builds on the content they are currently viewing. Creating immersive virtual experiences encompasses concepts of augmented reality and game play, relating to students' desires of having more hands-on experiences and better understand what it would feel like to be an astronaut. Communication between peers and NASA discusses the possibility of highlighting the more social and collaborative aspects of the application where students can either communicate with each other or possibly communicate with representatives from NASA (including flight controllers and astronauts).


DAFFODIL EXPERIMENT
BUTTERFLY EXPERIMENT
FLY EXPERIMENT


REPAIR OF AIR FILTER
MONITORED DATA
TEMPERATURE 70°F
Needs to stay between
otherwise
OXYGEN LV 5
HUMIDITY 80%

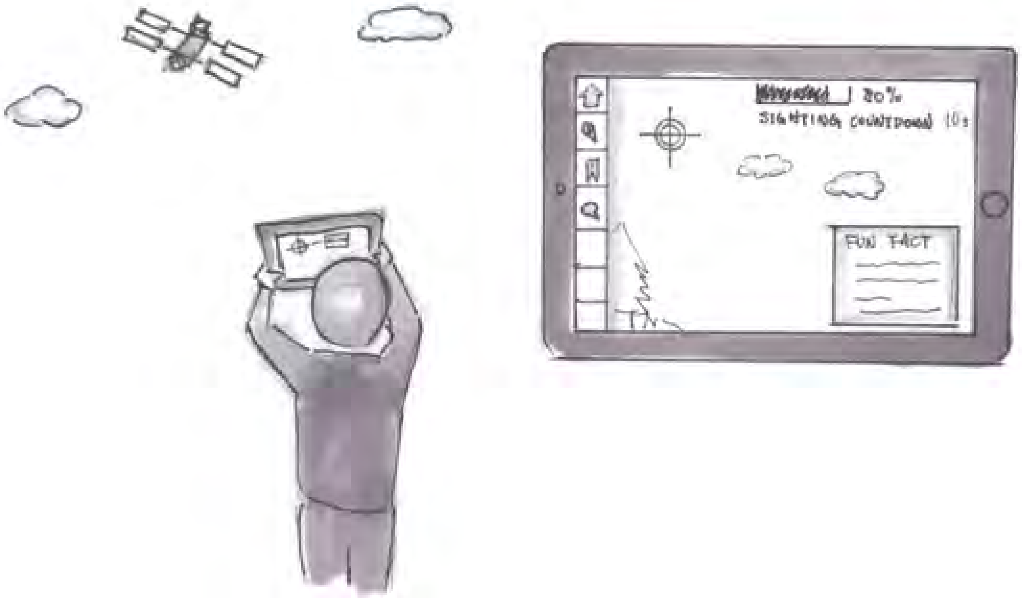
What if...

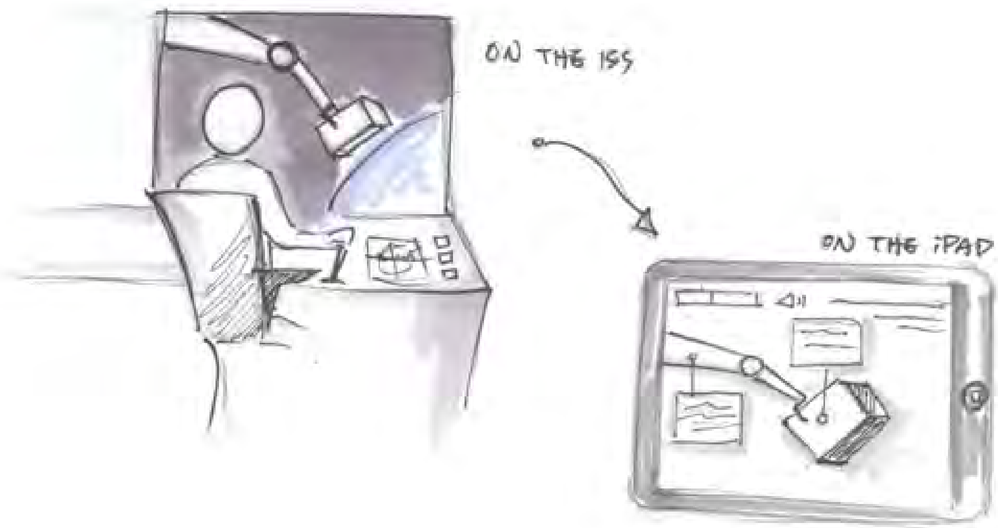
...scheduled ISS activities were shown in a personalized, dynamic, and educational way?

One potential vision for ISS *Live!* focuses on actual scheduled activities. Such an app could excite space enthusiasts like Steve by allowing them to see the "big picture" and current state of the ISS, while presenting this information in an educational and easy-to-understand way for less space-savvy students like Faith and Taylor.

Imagine, for example, if a student could open the application and immediately see the scheduled activities for the day (with greater visual prominence for more interesting activities). Perhaps a "highlights list" of exciting past activities could be available, from the construction of an early ISS piece to the repair of a critical computing failure that might have brought down the station. As shown in the concept sketch to the left, they could even see one scheduled activity and explore related ones: for example, viewing activities related to a science experiment around flies might suggest related ISS experiments for the student to browse.

A schedule-based product could provide an educational focus, too. Instead of just showing a live dump of telemetry data, imagine if scheduled activities were accompanied by a list of monitored telemetry data values: for example, "Repair of Air Filter" might include live levels of oxygen and explain why that data is important and what it should be if everything is progressing smoothly. Meanwhile, students might examine ongoing science experiments onboard the ISS; the application might provide directions for closely connected science experiments to try at home, and then invite the student to compare the results on Earth with what unfolds in space.


80%
SIGHTING COUNTDOWN 10s
FUN FACT


ON THE ISS
ON THE iPAD

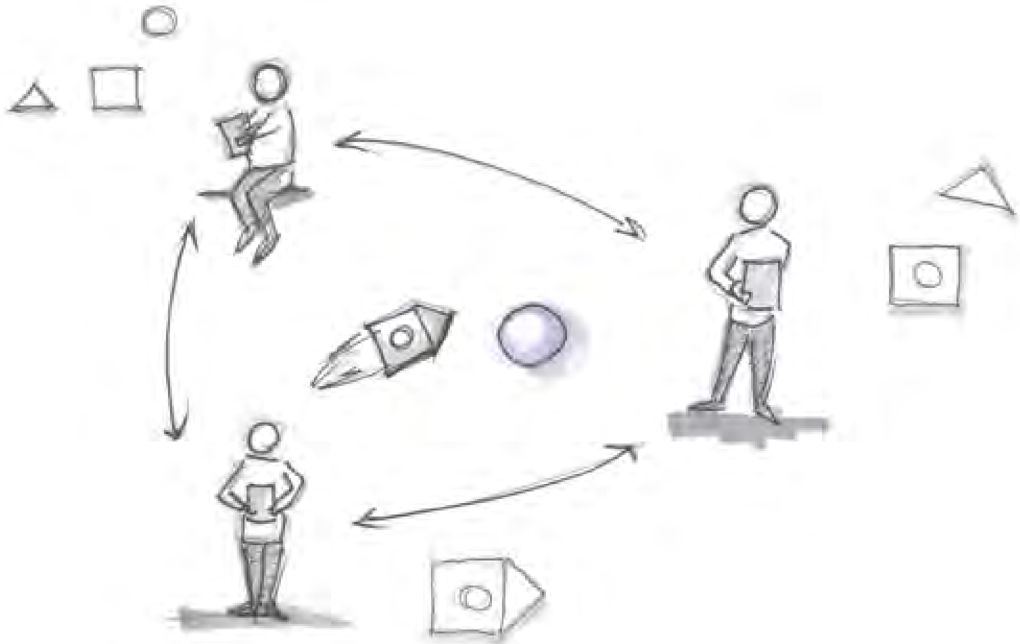
What if...

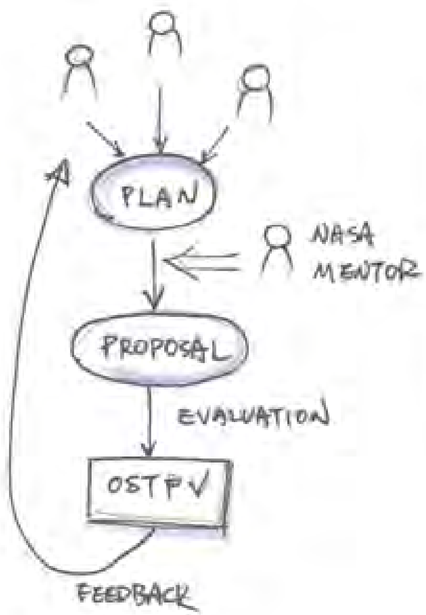
...we could use a virtual, hands-on approach that borrowed from augmented reality or gaming?

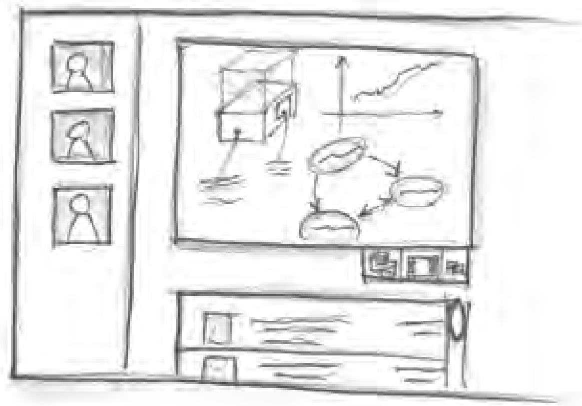
Our research showed that students desire a sense of control and prefer not to passively ingest content. Faith, for example, quickly skims large amounts of data and avoids reading long, dry passages of text when she can. Instead of directly showing large amounts of data, we could create a virtual world with data for Faith to explore. Using game mechanics and augmented reality, she can learn the same information in a much more enjoyable way.

We could, for example, use this method to allow students to track the ISS in the night sky and zoom in on details. Augmented reality typically makes use of positioning sensors on a device such as a tablet or smartphone and overlays a virtual world onto the real one. In this case, the virtual representation of the ISS could be overlaid onto the night sky given the real-time position of the ISS; students could zoom into this virtual ISS and explore it to see what astronauts are currently doing onboard the station as they are tracking it. This gives students a greater feeling of participation and builds a stronger connection between the data presented and the real world.

Another example could allow students to explore the activities on the ISS by following along on their own. Students could see what astronauts are currently doing on the station, launching a simple game-like exercise to better understand the mechanics and purpose of the activity. For example, if an astronaut is capturing a docking vehicle with the robotic arm, the student could use their iPad to complete a similar exercise and be evaluated on their performance. Students could also conduct virtual science experiments on their iPad that mirror those being conducted on the ISS. This could explain complex concepts without the need for dense text and give users a greater feeling of control within the application.




PLAN
NASA
MENTOR
PROPOSAL
EVALUATION
OSTPV
FEEDBACK



What if...

...we can enhance the collaboration amongst peers to fulfill a shared learning experience?

We envision this solution to help guide students like Faith to better understand themselves and where their passions lie in the process of choosing her academic/career path. Additionally, Taylor really treasures her time with her friends; this solution also has the potential to make space and science knowledge fun for her through peer interactions.

For example, imagine an application that allows students to form teams to tackle problems centered around the ISS. The types of problems can range from science problems the astronauts and ground crew regularly solve to various types of missions conducted by the crew. Visceral simulations and interactive components could guide the process while educating students and leveraging the touch screen and sensors of the iPad. Collaboration between students could be real-time or offline-synchronized. Such a concept could improve students' problem solving abilities and spark an interest in space-related topics through the same sense of collaboration towards a greater goal that intrigues NASA staff.

We also envisioned a possible collaborative platform that allows students to come up with interesting activities or experiments that can be conducted on the ISS during the crews' off-time. For example, students could form teams and use the application to make a project plan of an activity or experiment. The application would provide interactive content and real-time information about the ISS along with necessary project planning tools. In the process, the team can seek advice from NASA mentors or even the astronauts themselves. After finalizing a plan, the students could submit for reviews by NASA and possibly even see their work conducted on the ISS. This concept relies on the essence of teamwork and mentorship that guides students in the right directions throughout the learning process, and we could even see it becoming part of an interesting curriculum in science classes.

About Us

The Pausch Bridge at Carnegie Mellon connects drama and computer science buildings, symbolizing an interdisciplinary link between art and technology.

About the HCII

Carnegie Mellon's Human-Computer Interaction Institute (HCII) takes an interdisciplinary approach to ensure that technology harmonizes with and improves human capabilities and goals.

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:

Jenna Date, Director of MHCI
jdate@cs.cmu.edu
412 268 5572

Human-Computer Interaction Institute
Carnegie Mellon University
Pittsburgh, PA

Team Pyxis

Why "Pyxis"?

Pyxis is a small and faint constellation in the southern sky; its name is Latin for "a mariner's compass." The name seemed fitting and inspiring, in the hopes that we can head towards the right direction in the process of designing our product.

Nisha Kurani
Co-Project Manager

Nisha grew up in southern California, where she graduated from the University of California, Irvine in 2007 to earn a B.S. in Information and Computer Science. She discovered her love for enhancing user experience while working at a major ERP Implementation as a consultant for CSC (Computer Sciences Corporation). She prides herself as being a donut connoisseur, but also enjoys dancing and shopping.

Clifton Lin
Co-Project Manager

Clifton is an American citizen who spent most of his life in Taiwan. He earned his bachelors in electrical engineering from National Taiwan University in 2010. During college, he wasn't satisfied with learning circuits but luckily found his passion for HCI after taking a ubiquitous computing class. Outside of his coursework, Clifton enjoys street dancing, surfing and just relaxing.

Tony Poor
Design Lead

Tony has a background in design and computer science from CMU. He lived a past life as a web developer and has interned as a designer at Salesforce.com and Knewton. His excitement to work with NASA stems from the opportunity to design a product that has a profound impact on our knowledge of the universe. In his personal life, Tony loves dogs and good music (of any genre).

Namrata “Sony” Verma
Research Lead

Sony graduated from MIT in Brain & Cognitive Science. A former pre-med student, her interests in technology and program management led her to HCI. As the NASA Capstone project touches on fond memories of space camp, she is excited to apply HCI methods to kindle the same fascination for space and science in others. In her off time, Sony loves dance, volleyball, and old Bollywood songs.

Eric Dudiak
Technical Lead

Eric grew up in Atlanta and attended Georgia Tech, receiving a degree in Computational Media. He spent the last two summers working at Apple in roles combining software engineering and user experience design. Space exploration became a hobby for him at a young age when he participated in all three levels of space camp in Huntsville. Outside of work, Eric is also a very passionate skier.

Appendices

Appendix A: Models

Models aim to capture different aspects of interaction happening both amongst users and between users and the environment specifically within the context where this form of interaction takes place.

Due to our diverse research focus with different group of participants, different types of models were generated to help us understand the participant group and the context they are in. The following are short introductions of the types of models we have used:

Cultural Models

A cultural model highlights the values, expectations, desires, and the holistic approach people take in the observed context. It is important for understand the overall dynamics and interaction between different groups of people.

Sequence Models

A sequence model illustrates the order of the tasks that unfolds over time. This series of action will help us gain a better understanding of user intent in the process of the interaction.

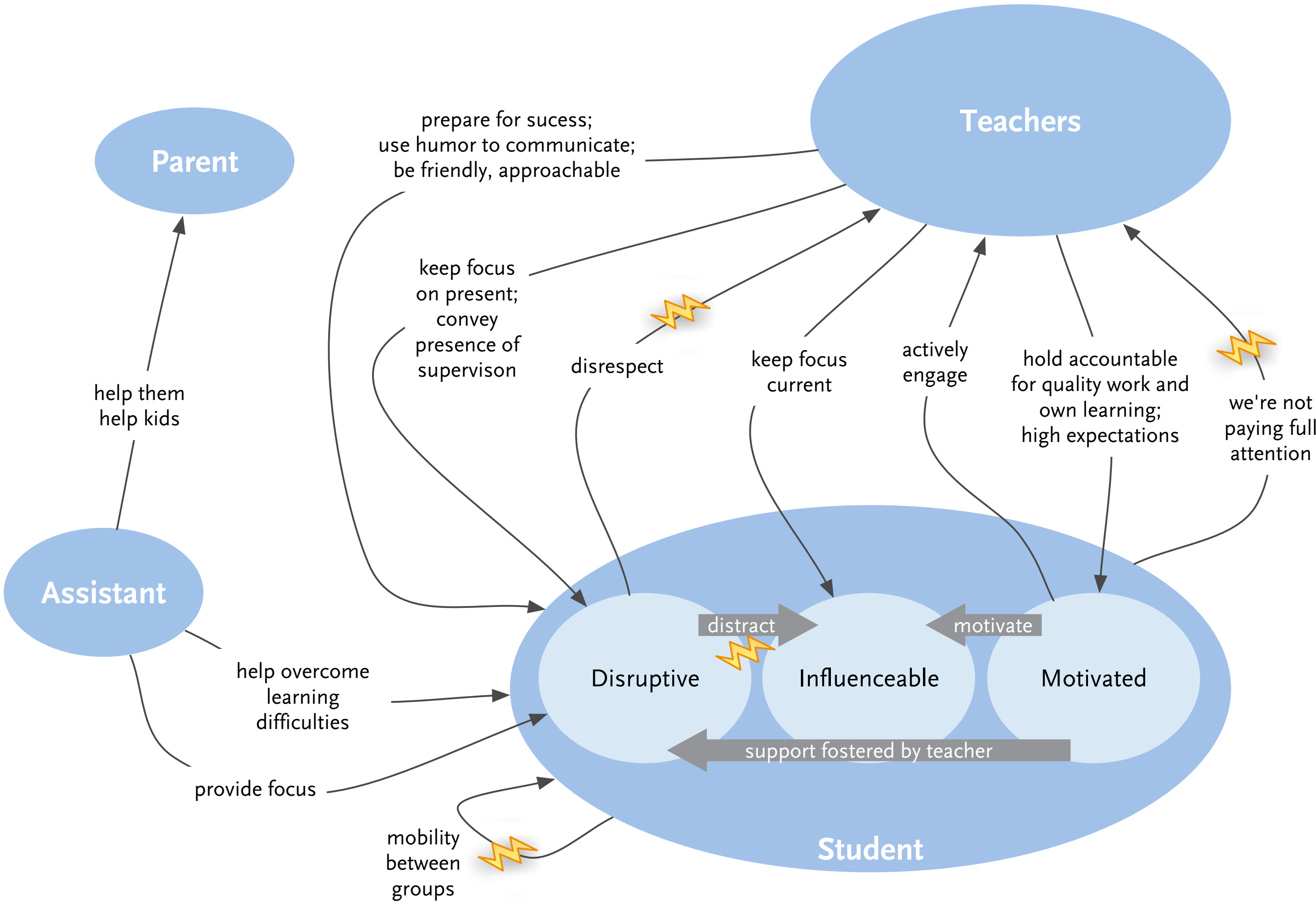
Artifact Models

An artifact model highlights the information presented, various parts, structure, and overall presentation of an object. This is particularly useful to evaluate the usage of a technology and while identifying the break downs that is also happening.

Appendix A: Models

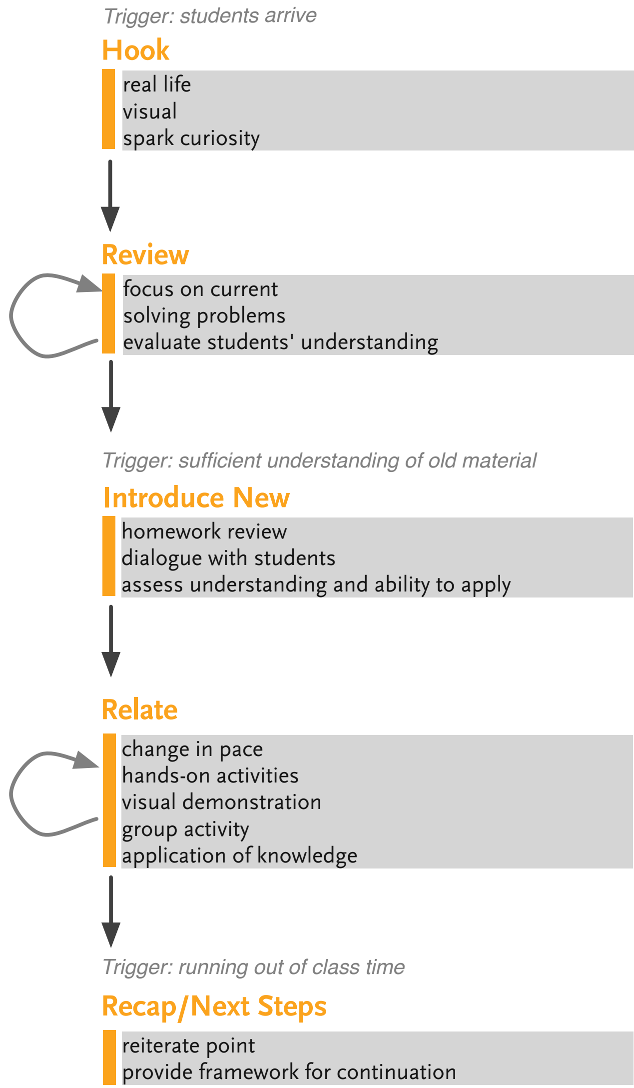
Cultural Model: Classroom Observation

This consolidated model helps us understand the overall dynamics between different groups of people to gain a deeper knowledge of how students and teacher influence each other in the classroom.



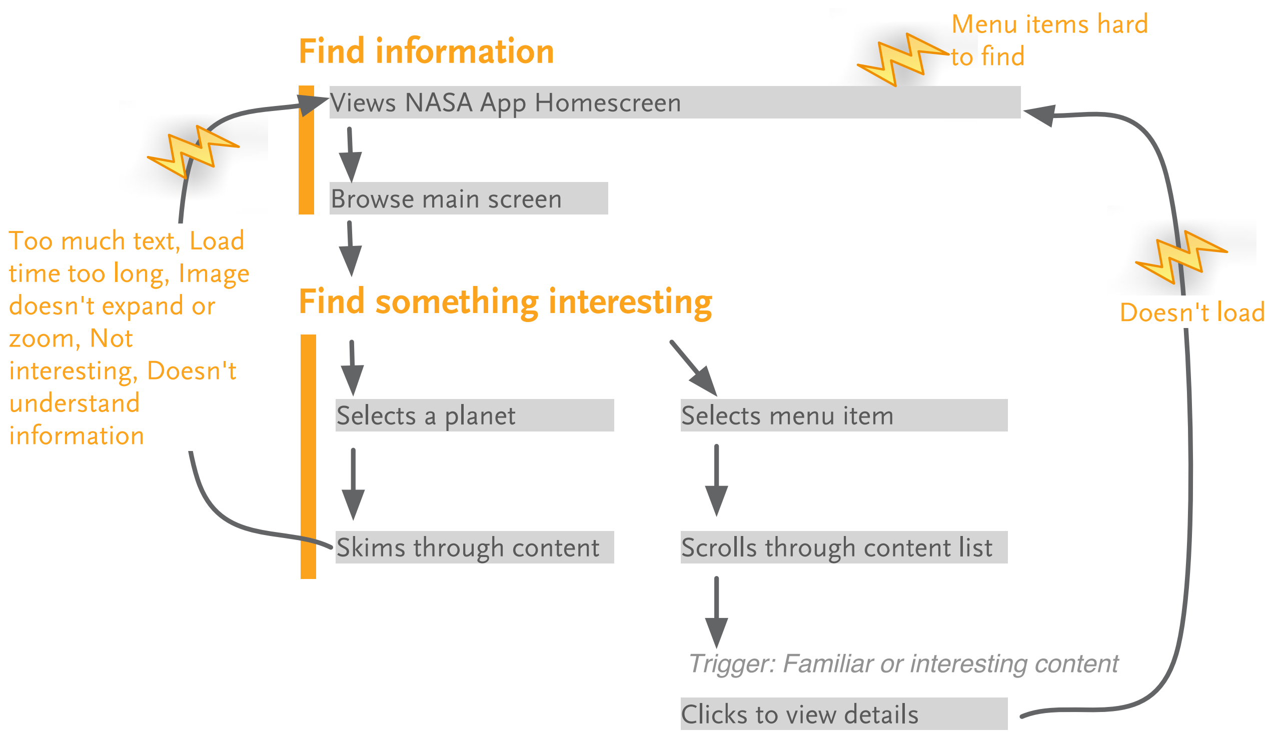
Sequence Model: Teaching Methodology

One of our goals in classroom observation was to understand how teachers convey knowledge to students, thus by extracting the steps as a sequence model is the best way to do this.



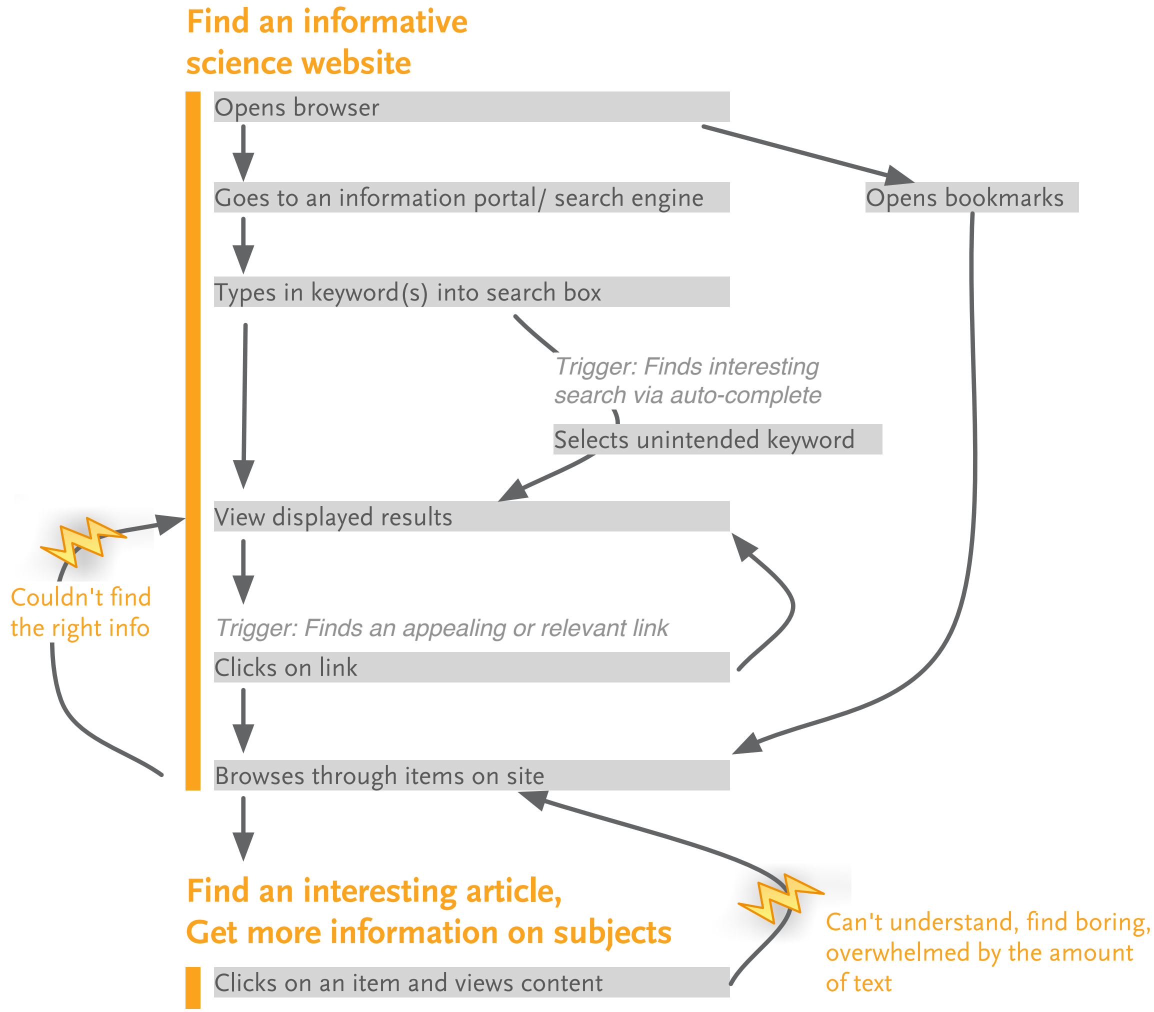
Sequence Model: NASA iPad Application

From this model we were able to gain a better understanding of what students like about the NASA iPad application and what they find frustrating.



Sequence Model: Web Content Browsing

From this model we were able to understand the process students go through in discovering science-related sites on the Internet and how they process the contents presented.



Artifact Model: NASA iPad Application

These consolidated artifact models helps us to point out the areas of the iPad application that worked better and ideas of what did not.

Users really liked the summary tab and thought it was useful

image not interactive

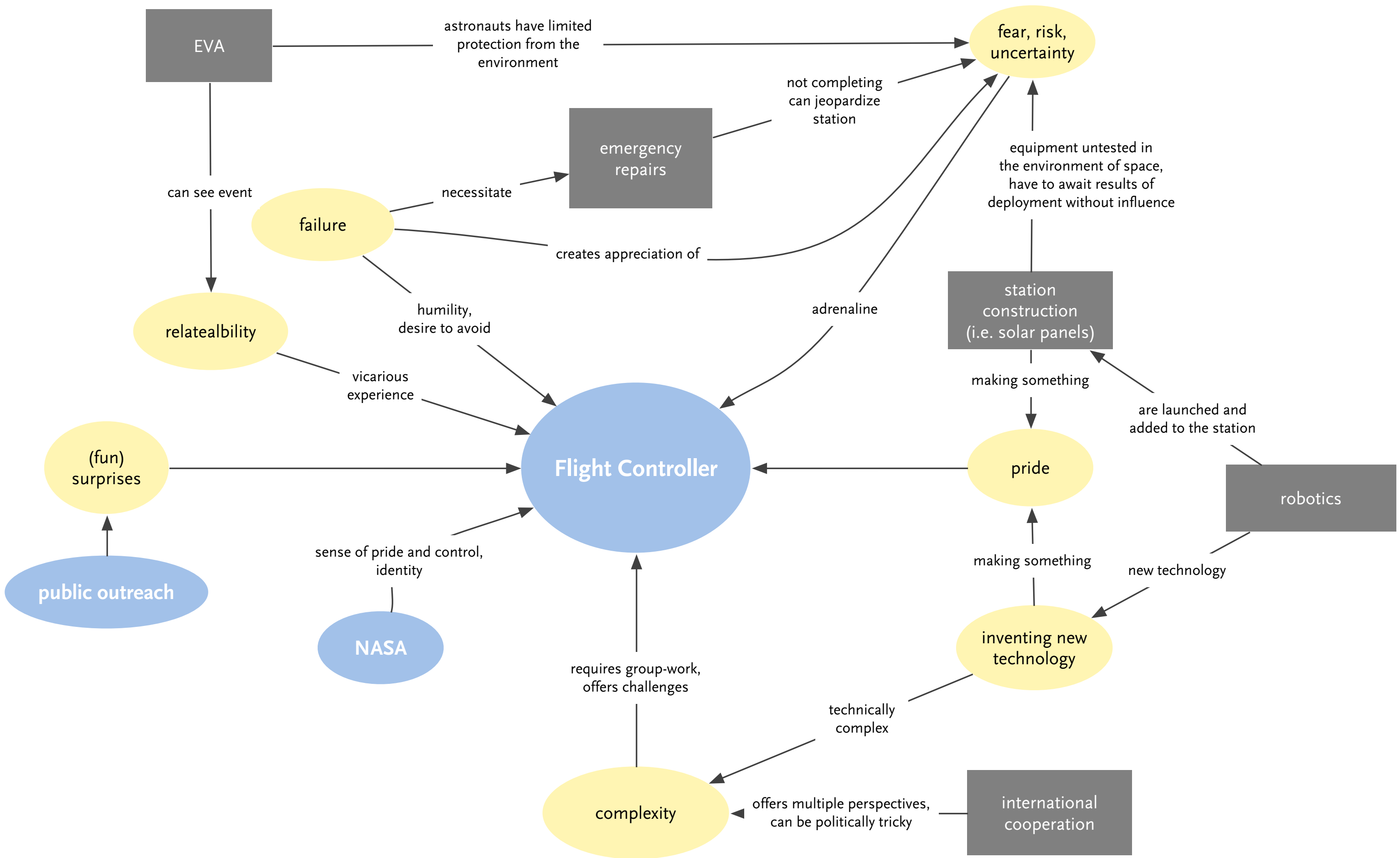
Homogeneity of text makes it hard to read ("maybe if they had it bold or italics, I could catch more...")

Smaller picture with caption caught more attention than big picture, because text had color (different color than link).

Appendix A: Models

Flight Controller Interest Model

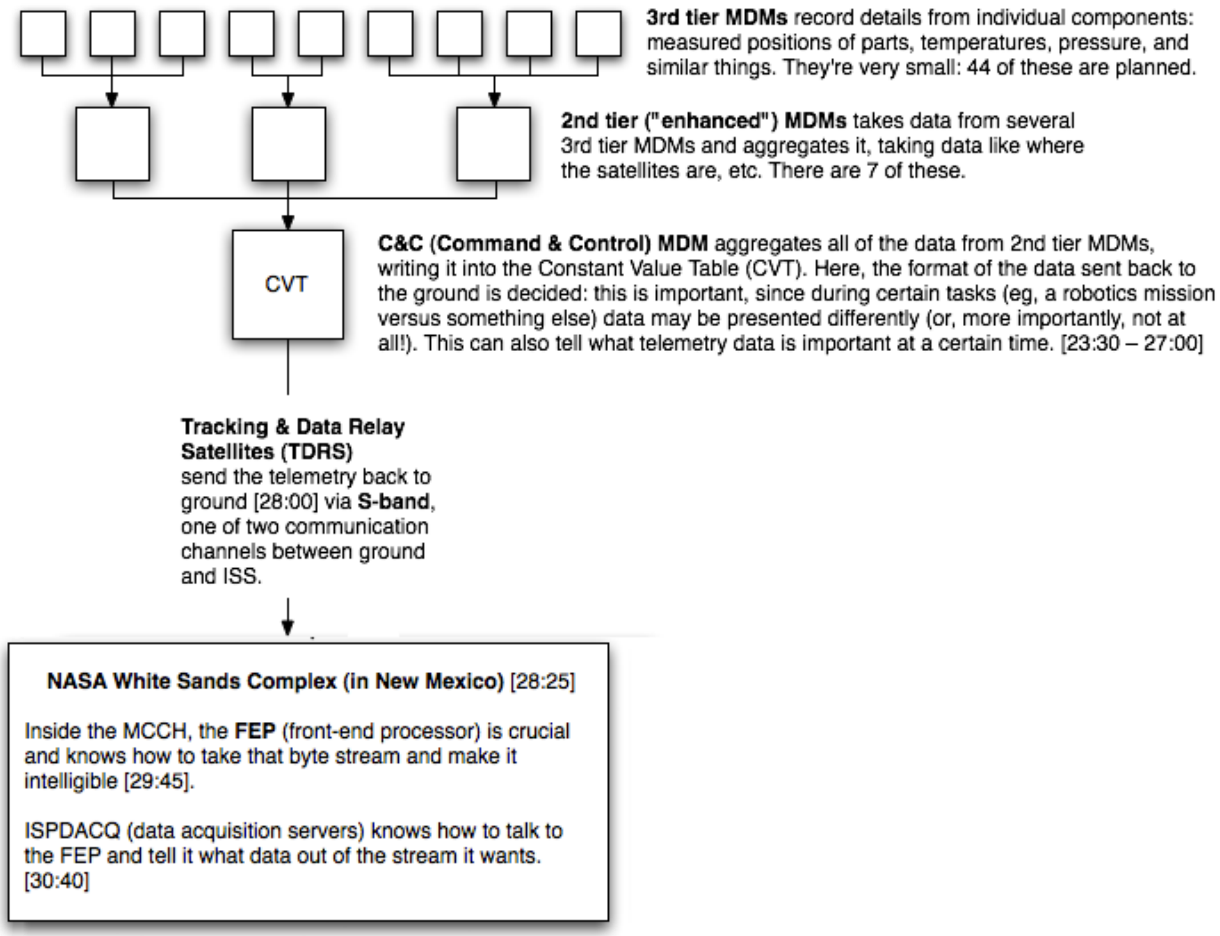
Using the cultural model from contextual design as a starting point, we integrated some of those concepts to help us better understand the flight control data we acquired during our activities at the Johnson Space Center.



Appendix A: Models

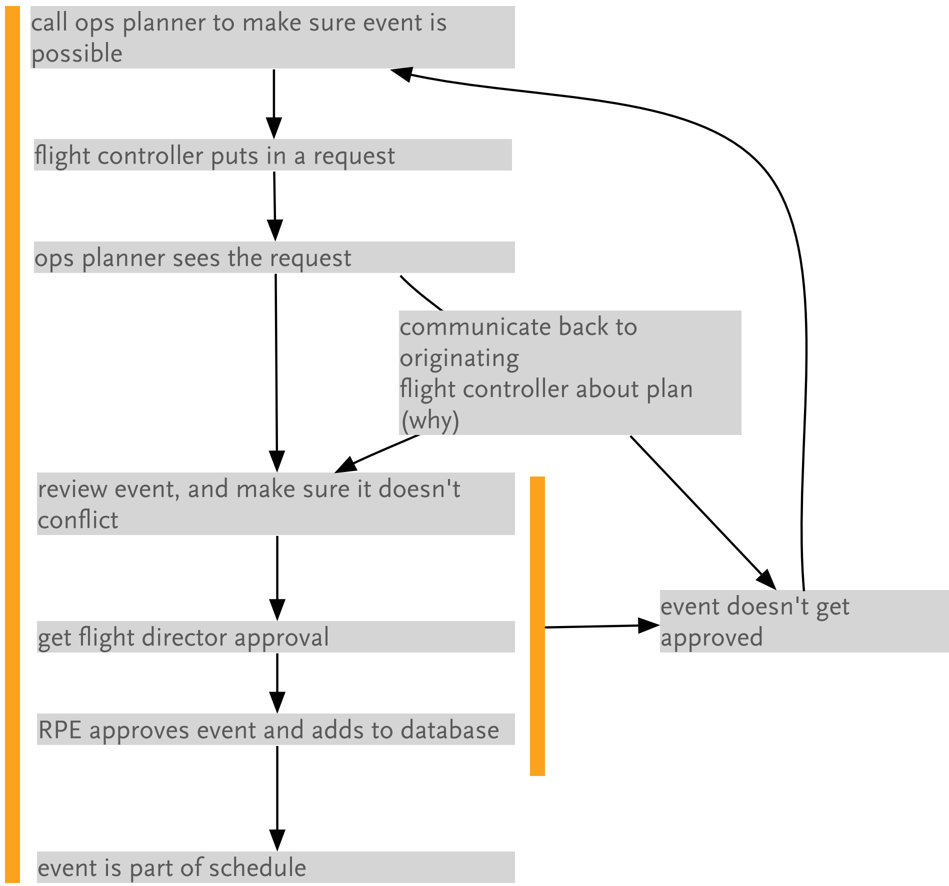
Telemetry Model

Following our interviews with flight controllers, we created a model of the telemetry process in order to understand how sensor data is collected and communicated between the station and the ground crew.



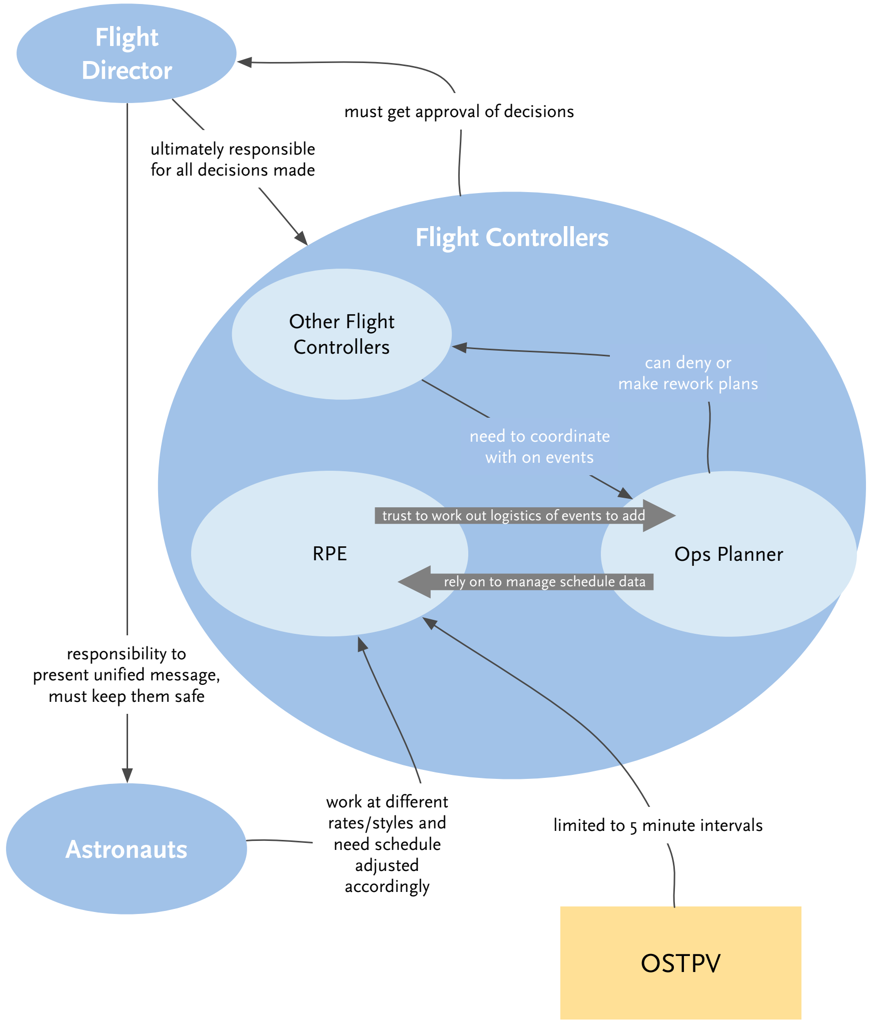
Sequence Model: Front and Back Room Flight Controller

The sequence model for the front and back rooms of the Mission Control Center helped us better understand the overall process of how an activity is created and used.



Flow Model: Front and Back Room Flight Controller

Through this model, we hope to highlight the influences different individuals had to better understand and validate what we learned while conducting observations in the front and back rooms.



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Appendix D: Digital Archive

This DVD includes additional appendix material from the creation of this report. This disc is designed to be read in any computer with a DVD-ROM drive.

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