



Alternate Reality Teaching: *OurSpace*

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INTIFIC™

Intific, Inc.

Principal Investigator: Dr. Amy Kruse

Executive Producer: Kristy Tipton

10814 Jollyville Road

Building 4, Suite 350

Austin, TX 78759

1-512-776-8281

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Final Report Phase 2

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Dr. Amy Kruse

Program Manager, Intific, Inc.

Michael Becker

Creative Director, Intific, Inc.

Kristy Tipton

Executive Producer, Intific, Inc.

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1. ABSTRACT

Computer games have the power to attract and hold children's attention for extended periods of time, often exceeding that of the classroom environment. Intific's *OurSpace* program has been designed and developed to offer an innovative game system tailored to spark the interest of Pre-K to Grade 3 students in scientific concepts and lay the foundation to master STEM learning. The game environment is hosted on the Internet and allows various levels of educational interaction and play with graphics and related concepts of Social Emotional Learning (SEL), to interest and inform students while collecting metrics that can be used by educators to assess the performance of each individual student.

DEVELOPMENTAL APPROACH: Our plan is ambitious: to create a completely new way of using the tools of our modern technological culture to change how children feel about being educated, how teachers join in their students' journey, how our society engages in directing that process, and how learning becomes an integrated whole that moves along the same path that our growing global technical interdependence compels us to travel. To accomplish this Intific created a future-facing space theme, designed a platform for hosting games called *OurSpace*, and designed both a prototype and a final version of one game called *RoboBall* from a suite of potential STEM topics, continually improving, focusing, refining, and testing that game throughout Phase II. Intific's initial *OurSpace* game *RoboBall*, a proof-of-concept game exemplar that focuses on Physical Science and Science as Inquiry involving an interactive understanding of force, motion, and gravity. *OurSpace* serves as the educational Portal that the *RoboBall* game is hosted from. It allows access to the game, the data and the editor and is designed for future crowdsourced refinement and so that additional learning games can be easily hosted.

CONCEPTUAL APPROACH: Intific's *OurSpace* program is designed to be a platform that fuses of videogame and next-generation learning systems to address our emerging needs: it is a platform using games that create a multi-student online learning environment that can be populated with an ever-expanding variety of learning experiences. *OurSpace* is also based on a novel toolkit approach that lets students create their own future by having learning tailored to their chosen field through *ART (Alternate Reality Teaching)*. In such a game and learning environment every student is given, initially through the DARPA ENGAGE program's games, the key visualizing building blocks of thought and learning (*Visual Thinking*, Arnheim, 1969), and as students advance – 'leveling up' in the parlance of the game industry – they tailor learning to their desires. Playing together in their own virtual communities, students could sharpen their critical thinking and logical reasoning skills as they strive to 'win' entertaining videogames with deeply imbued learning and tailored to their specific educational needs. Using these tools, students will also learn to share, emphasize, and cooperate with each other to win and succeed, improving peer relations, lessening bullying and laying a foundation for Social Emotional Learning (SEL). The overall

process used in *OurSpace* we call Alternate Reality Teaching (ART), the logical extension of highly acclaimed Alternate Reality Games (ARGs) of video gaming, and we believe that this unique approach aligns exceptionally well with the Standards-based Education approach of this program.

THEMATIC APPROACH: The *OurSpace* program is designed to use a space theme to capture the imagination of students of all ages, while embracing flexibly by adding modern educational research on learning strategies, gender and gaming, and social emotional learning. The *OurSpace* program provides us with a unique opportunity to make curiosity a beacon for future generations by creating a familiar yet very new online franchise vision that connects emotionally, socially and intellectually with this growing student audience and realizes that vision using the most qualified development team possible. This approach combines both the space exploration theme of many successful entertainment properties and leverages technologies for interconnectivity and communication to create a new, shared learning space that becomes OURS, as opposed to MINE. These elements, taken together, create an entertainment spectrum for gaming that evolves in sophistication as students advance in age, so that learning is additive and integrated as opposed to siloed and restrictive as the current learning approaches provide.

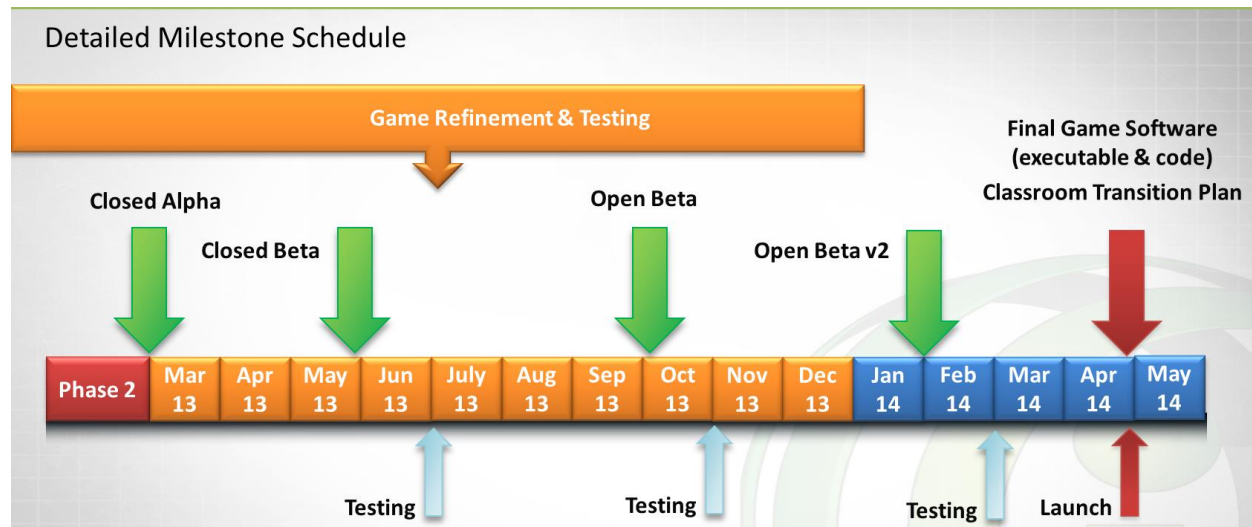
As veteran software developers, has been is gifted with powerful new tools with which to ply our trade. Computers, the Internet, Social Media, Databases, Mobile Devices, Portable Tools and an astounding array of technological innovations now cover our workbench. Our plan is ambitious: to create a completely new way of using the tools of our modern technology culture to change how children feel about being educated, how teachers join in their journey, how our society engages in directing that process, and in how learning becomes an integrated whole that moves along the same path that our growing global interdependence compels us to travel.

Intific believes and our initial (and future) test results will demonstrate that in the modern digital age it is now possible to fuse this method of self-paced learning with classroom processes and guidance to energize students in achieving greater levels of interest and performance in Science, Technology, Engineering and Mathematics (STEM) topics. The cumulative nature of computer game progression ties extremely well the educational layering required to teach STEM and even SEL related material.

Our research and development in this final phase of *OurSpace* also made clear to us that our approach to educational training benefits from being configurable or modifiable by the educators in order to adapt the material to the learning styles, capabilities and ultimately the disabilities of individual students. In this program the feedback obtained through collected data, metrics and analytical tools have assisted our educators and teams in rapidly identifying the changes needed for each individual or for the group as a whole. Initial testing also indicated that there will be occasions when additional educational levels need to be added in order to effectively convey and expand upon the original game approaches.

2. SUMMARY OF THE OVERALL PROGRAM EFFORT

The initial *OurSpace* game created by Intific is called *RoboBall* and it is hosted on a server accessible by any student, using a web browser from a mobile device with Internet access, and the overall system was developed according to the following phases, with this summary of 2014 concluding efforts.



PHASE I: The overall development objective of the program in this phase was to have a functional prototype in the first 8 months, and this was achieved through cooperation amongst the Intific Team (University of Denver, Texas A&M University, and Digital Steamworks) as well as extensive collaboration with CRESST/UCLA and the DARPA staff. We would like to recognize all these groups for their assistance and invaluable contributions which are summarized below.

PHASE II: In this phase Intific focused on refining the ENGAGE concept while incorporating DARPA's feedback into the ongoing improvements that were made. This included building a Test-Ready game for CRESST at UCLA to use to evaluate the effectiveness of gameplay and learning progression, and working with BrainPOP and Sesame Street in receiving feedback to develop an effective classroom transition plan. This was all done by using the in-game assessment data generated from *RoboBall*. The data was accessible from the *OurSpace* website where *RoboBall* is hosted. Researchers could view up to 100 data logs on a single webpage or download a .csv file for further examination. The game captured every piece of data from gameplay, with the information most frequently used by research partners made readily accessible to make reviewing test results more expedient.

2.1. PHASE II FOCAL AREAS

Intific worked closely with our CRESST/UCLA, BrainPOP, and Sesame Street partners to refine the prototype design during Phase II. Key Phase II Focal Areas included:

- TA-2 Collaboration to identify Physics, Prediction and Social Emotional Learning designs.
- Build a Test-Ready game to be used for focus testing.
- Provide data from gameplay to aid in assessment.
- Refine the editor and tools used to create *Roboball*.
- Collaborate with Sesame Street Workshop to leverage their insight.
- Transition our game to BrainPOP to facilitate the collection of "big data".

2014 ENGAGE Timeline						
2014						
External Party	Jan	Feb	Mar	Apr	May	June
DARPA	1. Monthly Report	1. Monthly Report	1. Monthly Report 2. Classroom Transition Plan	1. Monthly Report 2. Updated GDD/TDD	1. Monthly Report 2. Phase 2 Final Report	Project Complete
BrainPOP	1. Finalize agreement 2. Design changes	1. Start integration to BP Jr. site 2. Provide BP with "game assets"	1. Integration Complete	1. Transition Support	1. Continue Support if needed	
CRESST	1. Review Test Feedback 2. Discuss remaining testing	1. Final Release of RoboBall 2. Begin Writing Classroom Transition Plan	1. Complete Classroom Transition Plan	1. Begin writing the Final Report	1. Complete Phase 2 Final Report	
Sesame St.	1. Send documentation and game link	1. Review RoboBall 2. Provide initial feedback	1. Supply feedback for the Classroom Transition Plan	1. Provide input for the Final Report	1. Provide RoboBall review documentation	

2.2. KEY PROGRAM MILESTONES

The *OurSpace* platform and the *RoboBall* game were developed according to the following major milestones. Key activities throughout this program's full period of performance were:

- **Prototype Game** June 1, 2012 *Complete*
 - Flash Version: Deployed on Intific public server available to informed audiences
 - Support for CRESST/UCLA preliminary testing
- **Test Ready Game** Nov. 27, 2012 *Complete*
 - HTML-5 version, programmer toolset, requires game programmer
 - CRESST/UCLA individual trained
- **Test Ready Toolset** April 1, 2013 *Complete*
 - More robust toolset, more contributor feedback
- **Final Version Game** April 30, 2014 *Complete*
 - Complete toolset, metrics, and controls
 - Crowd source-capable game ready for deployment

3. WORK ACCOMPLISHED IN PHASE I (BASE PERIOD)

In broad summary, during Phase I Intific built a prototype game called *RolloBall* for the *OurSpace* platform, and in Phase II we extensively refined that game. We did this by achieving quarterly milestones according to the Phase I tasks below as the foundation for all Phase II activity.

3.1. TASK 1: IDENTIFY DESIRED EDUCATIONAL OUTCOMES, STEM FOCUS, DEVELOP GAME CONCEPT(S) AND STORYBOARD(S)

Detailed Task Description

Complete

Our team, with input from CRESST (UCLA) and DARPA, developed storyboards and a list of learning objectives and other game function requirements for *OurSpace*. *OurSpace* is a story about a team of characters who must journey from their ecologically distressed world to three different planets in an effort to learn skills to repair their home. In the process, they end up helping the

residents of each planet. The design provided for differing learning objectives on each world with incremental levels teaching differing STEM concepts in a progressive manner.

Deliverables:

Storyboard document: Submitted 2 Nov 2011, and Approved

Game Design Document: Submitted 27 Nov 2011 and Approved

3.2. TASK 2: BUILD GAME, GAME ARCHITECTURE, & COMPLETE DEVELOPMENT TESTING.

Detailed Task Description

Complete

Our contracting group, Digital SteamWorks, quickly developed a Flash-based prototype of the game, implementing a total of 32 levels spread across the three worlds.

Intific concurrently developed the *OurSpace* web site and with features for capturing and reporting individual performance measures. Typical information captured involves mouse clicks, time measurements and achievements reached. Collectively we integrated this system and began hosting that environment and application on a Web Server in that May. CRESST/UCLA then started preliminary testing.

Denver University, with support from Intific, developed “*OurSpace* Adaptation: A White Paper” (included with this report) presenting concepts for analysis in Phase II. Adaptation may encompass many areas, so the team will evaluate these concepts, correlated with the prototype game metrics to determine what types of adaptation could be effectively implemented in subsequent development. The primary areas we are investigating are adjustment of game content for students with sensory disorders, adjustment of game teaching style based on learning styles of individuals, adjustment of game content and pacing through a teacher console, and real-time automatic game content adjustment based on player performance.

Texas A&M University developed concepts for further Social/Emotional Learning (SEL) objectives that could be incorporated into Phase 2 efforts, their analysis being performed on the Prototype Game. This included an investigation into how to successfully measure SEL through measures/metrics rather than in person through observation and interviews, which is highly beneficial in a game that is to be widely distributed.

One of the concepts in the early DARPA project discussions was Crowd Sourcing. While this concept is still being refined with BrainPOP, when coupled with the concepts of Adaptation, it became obvious that a customizable environment needed to be created to support the further objectives. Intific developed a “Game Creation Framework” which will be used to support the future objective and allow *OurSpace* to evolve. In this task Intific successfully transformed 3 key levels of the prototype game into this platform and will further develop the environment and convert the *OurSpace* game into this framework in order to support the Phase 2 Test Ready Game Objective.

Deliverables:

Alpha game software: Submitted 28 Feb 2012

Beta game software: Submitted 27 Apr 2012

Prototype game software: Submitted with this report

Source Code: The source code for the Prototype Flash based program was sent on a DVD via FedEx. The source code and configuration instructions for the Web Server which is built upon commercial products is not included on this DVD*.

Executable: The executable for the program is hosted upon a web server. Intific has hosted this on a public space which is accessible to DARPA/ONR and other teams. We will continue to host in this space during Phase II so that evolutions are visible to the entire team upon release. The location of this portal is <http://engagedemo.intific.com/>. The user may register at this location and create an account for their use. Once a user has logged in the initial attempt to play the game will require two additional credentials. These credentials will be emailed to DARPA under separate cover.

**Intific will provide the list of third party products and develop a configuration instruction for the government if required. Since this is a rapidly executing program with the next delivery in Phase 2 scheduled for November, and the Prototype Game will be replaced with a more functional game engine, we have not now spent the time preparing instructions and process for external parties.*

3.3. TASK 3: PROGRAM MANAGEMENT

Detailed Task Description

Complete

Intific has coordinated the efforts of our team with the overall objectives of the program and the periodic DARPA-led meetings. The development of the initial game was completed earlier than originally forecast, allowing us to focus on the quality of the experience and the depth of the metrics measured.

Deliverables:

No Physical Deliverables

3.4. TASK 4: MEETINGS, DOCUMENTATION & REPORTING

Detailed Task Description

Complete

Team participation in the DARPA meetings yielded multiple benefits to our development program. Our documentation has been delivered and accepted along with our reports.

Deliverables:

Slide Presentations: Submitted 17 Aug 2011

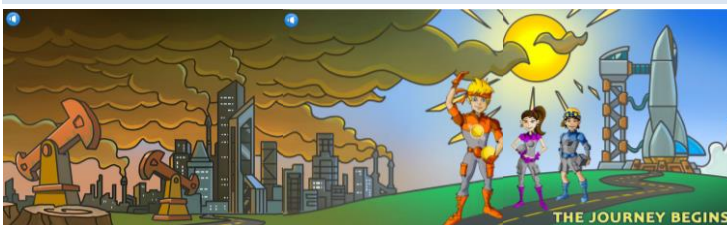
Monthly Reports: Submitted as required

Final Phase Report: The Phase I Report document

Implementation Documentation: Due 1 Month after Phase 1 complete (20 Jun 2012)

Technical Papers: Provided.

3.5. PHASE I SAMPLE DESIGN VISUALIZATIONS



In demonstrating the changes to the *RoboBall* game undertaken in Phase II, it is useful to conclude a Phase I

summary with a keyframes of how the initial prototype game operated.

This prototype game had thirty-two (32) levels spread across three Worlds. A Progression chart served as the master list of the levels, which was created by merging the learning progression with the game skill progression in a manner that served the goals of each. The result was a game that introduced game mechanics in parallel with learning targets. These screens below show Level 1 from both Worlds 1 and 2.



Game World 1



Game World 2

4. WORK ACCOMPLISHED IN PHASE II

Guided by the ENGAGE goals of facilitating young student interest in Science, Technology, Engineering and Mathematics (STEM) topics through involvement in education game playing, in Phase II Intific worked with CRESST/UCLA, Sesame Street Workshop, and BrainPOP to fully develop a revised version of our physics-based educational game. The specific Task elements in Phase II were:

4.1. TASK 1: REFINE THE ENGAGE GAME CONCEPT

- Primary: Intific, Inc.
- Supporting: Intific, Inc., Texas A&M, and the University of Denver

Detailed Task Description

Complete

In this task, the Intific-lead team will reevaluate the game concept to be executed in Phase 2. The team will integrate feedback from DARPA, educational experts on our team, and other members of the ENGAGE TA-2 community. As part of the refinement process, the game concept will be aligned with customers (students) as identified by the TA-2 ENGAGE participants.

Deliverables:

- Revised game design document, as part of the living documentation of the software development.

Exit Criteria: Submission of documents and DARPA approval of documents.

University Contribution: Both Texas A&M and University of Denver played significant roles in evaluation of the pedagogical aspect of the game and game play.

4.2. TASK 2: BUILD TEST-READY GAME

- Primary: Intific, Inc
- Supporting: University of Denver

Detailed Task Description*Complete*

Intific will be responsible for the creation of a test-ready game for the ENGAGE program. This will involve the production of games as described in Phase 2 of the technical plan within this proposal and influenced by the activities of Phase 1. The preparation for deployment and use within the TA-2 area will involve a rigorous Q&A process to ensure that the game is playable, major bug-free, and useable by children of the appropriate age category.

Deliverables:

- Test-ready game software, 6 months after Phase 2 contract award.

Exit Criteria: Submission of software executables, and DARPA receipt of software.

4.3. TASK 3: FUNCTIONAL TESTING, REFINEMENT OF GAME & FINAL GAME DEVELOPMENT

- Primary: Intific, Inc
- Supporting: University of Denver

Detailed Task Description*Complete*

Based on input from and interactions with TA-2 providers and students using the game, Intific, Inc. will augment, edit, or revise the game during the main testing period. These are assumed to be quarterly updates, allowing time for the development team to respond to needed changes.

Deliverables:

- Revised game software: delivered as either updates or new executables, quarterly following the initial release of the test-ready game software.
- Final Game software: delivered to DARPA at 23 months after Phase 2 contract award.

Exit Criteria: Submission of software executables, and DARPA receipt of software

4.4. TASK 4: INTERACTION WITH TA-2 PROVIDERS

- Primary: Intific, Inc.
- Supporting: University of Denver

Detailed Task Description*Complete*

This task is primarily a coordination task, but involves interaction with the ENGAGE TA-2 performers. As TA-2 will be responsible for the test plan and overall deployment of the game software, Intific, Inc. will collect inputs and distribute them to the developer and various educational partners. University of Denver will assist with communication to the TA-2 team.

Deliverables:

- Input to be used by Intific, Inc. in the execution of Phase 2, no formal deliverables.

Exit Criteria: Occurrence of interaction, likely via teleconference.

University Contribution: University of Denver will assist with communication to the TA-2 performers.

4.5. TASK 5: PROGRAM MANAGEMENT – INTERNAL & EXTERNAL PROGRAM COORDINATION

- Primary: Intific, Inc.
- Supporting: Texas A&M University

Detailed Task Description

Complete

This task is the program management and coordination task. This will be an Intific, Inc. lead task, since Intific will be responsible for pulling together all of the various subcontracting entities and TA-2 performers. Intific will also serve as the main interface to DARPA through the management roles assigned to this effort. Supporting Intific in this role is Texas A&M University, who will assist with coordination of the various university entities in the effort.

Deliverables:

- No physical deliverables. Outcome is team coordination as described in the Management Plan section of this proposal.

Exit Criteria: Occurrence of meetings and teleconferences as planned.

4.6. TASK 6: DARPA PROGRESS MEETINGS, DOCUMENTATION & REPORTING

- Primary: Intific, Inc.
- Supporting: Texas A&M University, University of Denver

Detailed Task Description

Complete

This task supports the various meetings, reports and documentation required as deliverables for the DARPA ENGAGE program. In the role of integrator, Intific, Inc. will take primary responsibility for the presentations and reports. Intific will be supported by Intific, Texas A&M University, and University of Denver in the production of all data, screen shots, and text required to complete the items. The publication of technical papers will be led by Texas A&M University and University of Denver through their respective academic institutions.

Deliverables:

- Slide Presentations: 1 month after Kickoff meeting, 1 month after annual review
- Monthly Progress Reports: Monthly, starting 30 days after Phase 2 contract award
- Final Phase 2 Report: 24 months after contract award
- Implementation Documentation: 1 month after end of Phase 2
- Technical Papers: Written and published as appropriate during the effort

Exit Criteria: Submission of documents to DARPA with DARPA receipt of materials.

5. PHASE II, TASK 1 - NEW DESIGN AND DEVELOPMENT DIRECTIONS

5.1. WHAT IS ROBOBALL?

In *RoboBall*, students learn both physics and social emotional learning concepts through problem solving. The goal of the game is to make the RoboBall reach a treasure chest while avoiding

colliding with an asteroid. Students manipulate different variables (force direction and magnitude, mass) to control the motion of RoboBall.

5.2. SUMMARY OF GAME REFINEMENT RECOMMENDATIONS FOR TASK 1

In Phase II Intific's educational partners provided a great deal of input and insight into game refinements to best align the overall experience with the required STEM and SEL learning objectives. The above section highlights the visual and play changes as implemented because of these recommendations. The following sections call out those recommendations in more detail, and how Intific subsequently modified the overall *RoboBall* game in Phase II.

CRESST's Feedback	Solution
1.Problematic introduction to concepts (sequence and confounding variables).	1.The September release will have demonstration levels that communicate the concepts covered in the upcoming levels. 2.Creation of "units" that build on a specific game mechanic and learning target.
2.Knowledge of relevant physics in not useful in solving puzzles.	1. We have built scaffolding that builds up the learning progression and game mechanic intuition.
3.Presence or Absence of gravity is not explicitly communicated.	1. There will be storyboard and in-game art that communicates that absence of gravity. This will include a world in which all levels are played in space, so the art communicates that the gravity is negligible.
4.More icons are needed for the relevant physics concepts.	1. There will be graphical aids for visualizing mass, gravity, and distance.
5.Achievements should be more closely tied to learning goals and objectives of the game.	1. With the adaptive learning levels, every level is tagged with the specific learning goal it corresponds to. This will allow us to give more accurate achievements based on the learning progression.
6.In the Achievement viewer, Social Emotional Learning is referenced as an acronym; SEL. Young children will not understand this.	1. With the introduction of learning based achievements, this will no longer be an issue. 2. The reference will be replaced with another term.
7.Character use or appearance frequency may favor certain characters.	1. The character use has been evaluated and we will adjust when and where the characters are shown.
8.Social Emotional Learning scenarios designs may need another revision.	1. In general, the development of the SEL scenarios takes 3 weeks per scenario, we have worked with CRESST to design each scenario and show iterative progress throughout the creation process. 3. We will revisit the tuning of the scenarios after Sept. 30th.
Sesame's Feedback	Solution
1.There are no stakes for losing or incorrectly answering.	1. There will be a system implemented that tracks the # of attempts in a given unit. 2. The player will have a chance to use each crew member to complete the level. If the player try's and fails, the art will indicate that they have one less attempt left by showing the character greyed-out.
2.Each world should have consistent properties, so as the player moves through the game they can use their past experience and knowledge to solve future puzzles.	1. Moving forward each world will have specific "environmental" properties, ex., gravity or negligible gravity.
3.The introduction of new elements need scaffolding.	1.The September release will have demonstration levels that communicate the concepts covered in the upcoming levels. 2.Creation of "units" that build on a specific game mechanic and learning target.
4.It would be nice to have voice over for tutorials.	1. One of the restrictions for this project was the classroom environment. Due to the noise restrictions and the use of headphones in the classroom, we decided to deprioritize the production of sound. 2. We can revisit this issue after Sept. 30th.
5.The story line seems a bit disjointed from the rest of the experience.	1. The storyline has been revisited.
6.The tutorials should be interactive.	1. We are working to make the tutorials interactive for Sept. 30th. 2. Players will be able to interrupt the tutorial video by clicking in the frame.

Note that BrainPOP also provided extensive input on the *RoboBall* game, and that feedback is included at the end of this report as it pertains to next-step activities involving this program.

5.3. GAME REFINEMENT AND TECHNICAL DESIGN OVERVIEW

The purpose of the following material is to familiarize the reader with the design changes made to *RoboBall* throughout Phase 2, based upon the feedback summarized above. This material illustrates and explains the game designs, mechanics and technologies used to create the most recent version of the game.

This portion of this Final Report covers the “why’s and how’s” of the creative and technical design.

5.4. STORY REDESIGN PROBLEMS

This section describes changes made to the story in *RoboBall* and explains revisions made to alleviate problem areas. *RoboBall*’s initial story suffered from the following problems:

- Story narrative was too involved to communicate in the stand-alone game
- Story elements did not match physics game play elements
- Story elements did not match SEL game play elements

Given that *RoboBall* will function as a standalone online game, the team decided to make the story self-contained within the digital experience so that it does not require peripheral storybooks or similar devices. Additionally, previous efforts to unite game play and story have introduced extraneous game play elements that distract from the physics mechanics.

Rather than add elements to the game to support a story that is too large to convey, we also reduced the scope of the story to match the elements already present in the game. This editorial scoping also serves to add greater emphasis to the desired elements.

5.5. STORY REDESIGN SOLUTIONS

Based upon educator feedback, we reduced the scope of *RoboBall*’s storyline in the following ways:

1. Audited existing story elements, identified those which correspond to existing game elements
2. Consolidation: when a story element had an analog in the game, kept it, changing any visual or functional properties to match the existing game element
3. Streamlining: when a story element had no analog in the game, removed it.

The revised storyline:

A huge meteor has collided with the Queen's "World Ark," scattering it's cargo through space and across the planets of her home system. You and your friends must journey across the solar system and retrieve her peoples' treasures.

Consolidation:

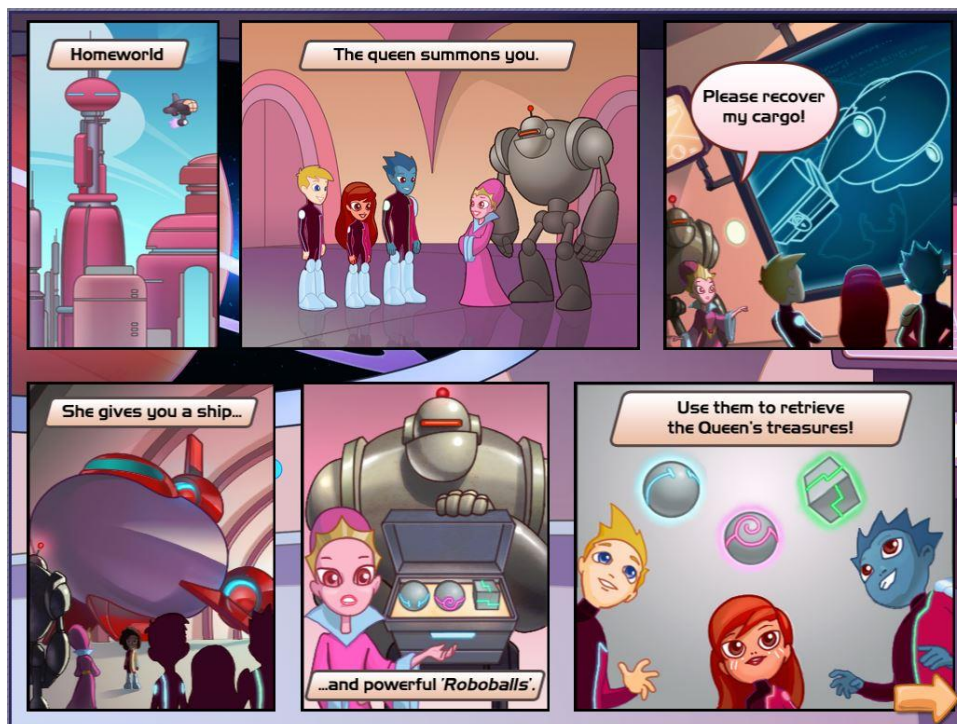
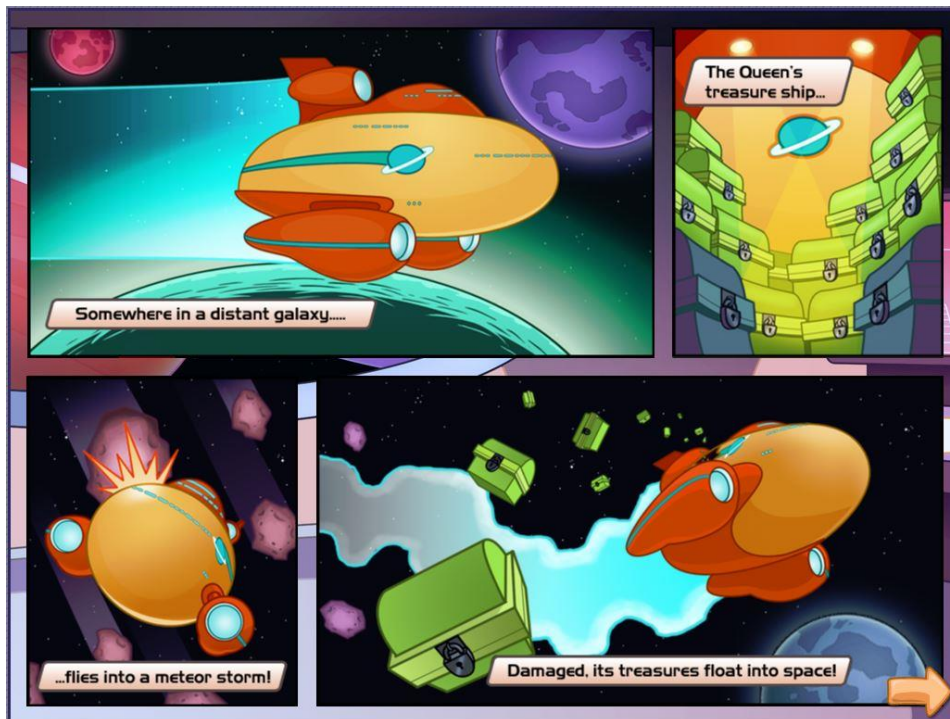
1. "Gifts" become "Chests," which match the treasure chests in the SEL.
2. SEL levels communicate the opening of chests to retrieve the collectibles contained inside.

Streamlining:

Abandon idea of cleaning/restoring the planet

5.6. OUR GAME STORY TELLING APPROACH

The in-game approach to cinematic storytelling results in the following graphic novel approach to all *RoboBall* cinematics. These provide easy-to-read and exciting interludes that draw students into the game and provide context for all of their game and player interactions.





5.7. OUR SOCIAL EMOTIONAL LEARNING (SEL) APPROACH

The power of video games to remove the individual persona and create the compulsion to engage with a digital system may be powerful allies in addressing Social Emotional Learning. In Phase 1 CRESST/UCLA was tasked with developing the storybook to accompany the *OurSpace* system's *RoboBall* game that would expand the SEL storyline under educator-lead guidance appropriate to the educational and emotional maturity of the students.

Unfortunately CRESST/UCLA was unable to deliver this storybook. To keep the social emotional learning objectives intact, Intific developed storyboard intro movies.

These introductory in-game movies gave the players background information about the characters, and also set up the social emotional levels by presenting a situation in which they needed to identify the emotions the characters were feeling.

Examples of this are shown below.



Figure 4.0– Social Emotional Level 4 Intro Movie – Setting-up the social situation



Figure 4.1 – Social Emotional Level 4 Decision Screen – How do the characters feel?

5.8. PRIZES AND LIVES

Student engagement is vital in learning games and there were several recommendations of how to enhance it and create greater player motivation, as summarized below.

5.8.1. ENGAGEMENT AND MOTIVATION IN *ROBOBALL*

This section describes the "Prizes" and "Lives" systems in *RoboBall*. The "Prizes" system supplies mid-term engagement, while the "Lives" system provides motivation to solve levels through analysis rather than trial and error. Before we discuss prizes and lives in detail, we first provide an overview of Engagement and Motivation design goals for *RoboBall*. We then outline the goals and requirements for the Prizes and Lives systems.

Engagement refers to the game's ability to hold the player's attention over some period of time. *RoboBall* has three distinct units of time:

- Short-term: duration of a single level
- Mid-term: duration of a group of related levels, referred to as a "unit"
- Long-term: duration of a play-through of the entire game

Gameplay provides short-term engagement, and the story cut scenes provide long-term engagement. We've also added the accumulation of Prizes to supply mid-term engagement.

Motivation refers specifically to the player's desire to solve levels by thinking them through, rather than using trial and error. Previously, we had no motivational mechanics; so many students resorted to trial and error to solve levels. Now we are using limited Lives to motivate players to understand the physics principles required to solve each level.

5.8.2. PRIZES AND ENGAGEMENT

The concept of leveling up is prevalent in videogames and rewards are a powerful motivator for ongoing student involvement. A Prize System was also developed to foster mid-term engagement as follows:

- Each time a user successfully solves a level, the game awards him/her a Treasure Chest
- Chests remain closed until the player completes the last level in the current Unit
- If the player fails a Unit, he loses these chests he accumulated during that Unit
- When the player successfully completes the last level in the Unit, the game displays a variant of the "End Level" dialog box that displays an open chest filled with question marks
- When the player successfully completes the last level in the Unit, the game adds stickers to the player's "collectibles" pages, equal in number to the chests collected
- When the player completes the game, the game unlocks all remaining collectibles

5.8.3. LIVES AND MOTIVATION

Another important aspect of videogames that enhances player motivation by giving them 'skin in the game' is the concept of lives/attempts. The new Lives system provides motivation as follows:

- The player begins each Unit with 3 "Lives," represented by the 3 crew members
- Each time the player fails a level, one of the crew members "sits out" the remaining levels
- When the last crewmember "sits out", the player fails the current Unit and must start over at the Unit's first level

5.9. NEW USER INTERFACE REQUIREMENTS

In these redesign and enhancement efforts it became clear that *RoboBall* required several UI changes to support the new mechanics. Specifically:

- The 'Orb Meter' has become the Current Player Portrait
 - The portrait displays the bust of the current crew member
 - When the current crew member returns to the ship, the portrait displays the next crew member, and so on.
- The "Level Success" screen features a Treasure Chest instead of a Gift Box
 - The Chest will appear closed
 - The 'Rank' text has changed to "Chests"
 - The "Chests" text will display the number of chests so far collected in the Unit
- The "Level Failed" screen features the 3 crew members in addition to the Captain
 - Initially, the three crew members will all stand; as the player fails levels, each member, in turn, will sit down
- After the player completes the last level in a Unit, the game displays the Unit Success dialog variant
 - The Unit Success dialog's "Chests" text show the number of chests collected throughout the Unit
 - The Unit Success dialog displays a large, open chest filled with question marks
 - If the player returns to the main menu after seeing the Unit Success dialog, he or she will see the "New Collectibles" notification (shaped like a chest) on the Collectibles button

5.10. ASSESSMENT AND ADAPTIVITY DESIGN

This section outlines the current design for Assessment and Adaptivity within *RoboBall*. As we iterated on our designs, we updated this content to reflect the current state of the project.

RoboBall uses "pre-test" and "post-test" assessment levels to track student performance as a function of levels played. We have divided the game into "units" – groups of levels that address a specific physics concept. Most units start with "demo levels" that introduce new game mechanics. After the demo levels, students play a "pre-test assessment level" to gauge their understanding of the unit's physics concept BEFORE PLAYING ANY OF THE INSTRUCTIONAL CONTENT.

Next come a series of instructional levels, the number and nature of which change based on the player's performance (see 'Summary: Adaptivity' below). After completing the instructional levels, players must complete a "post-test assessment" which tests understanding of concepts from earlier units.

5.11. SUMMARY: ADAPTIVITY

RoboBall employs two forms of adaptive content management.

- First, it uses a "save-point" system common to many video games: if players fail three times during a unit, the game returns to the start of the unit.

- Second, it tracks player performance and assigns additional instructional levels to players scoring less than 80% on a unit's learning targets.

All of these tracking metrics are part of the overall evaluation data set available concerning the performance of each student.

5.12. REVISED GAME STRUCTURE

In enhancing *RoboBall* following the prototype version of Phase I, a great deal of new engineering was required. The game now relies on the following new game structures to implement our new assessment and adaptivity algorithms:

- **Units** – group of levels designed to explore a specific physics concept.
- **Demo Levels** – introduce new game mechanics. Has only one configuration, so students can't fail.
- **Pre-test Levels** – assess the student's understanding of new physics concepts **BEFORE** playing instructional levels that address the concepts.
- **Exercise Levels** – present new physics concepts in a variety of ways to appeal to different learning styles.
- **Adaptive Levels** – optional content provided to students who score lower than 80% on the Exercise levels.
- **Post-test Levels** – assess the student's understanding of physics concepts covered in the previous unit.
- **Social/Emotional Learning (SEL) Levels** – assess the student's understanding of social cues and interactions.

5.13. REVISED GAME FLOW

In order to accommodate the needs of Adaptivity and Assessment, it was also necessary that Intific the *RoboBall* game flow as follows:

1. The game consists of "units" of levels, with each level within a unit relating to the unit's overall learning goal.
2. If a unit involves a new game mechanic, the first levels in the unit will demonstrate this mechanic via demo levels.
3. Immediately following any demo levels, the user will play an assessment level, which measures students' understanding of learning goals.
4. After taking the initial assessment, students will play two or more exercise levels, designed to illustrate the unit's learning goal.
5. After completing the final exercise, the game will assess player performance and assign additional adaptive levels if the player's score falls below 80% on relevant learning targets.
6. If assigned no adaptive levels, or once finished with adaptive levels, the player will play a "post-test" assessment level.
7. After completing the post-test assessment, the player must complete a social/emotional learning level (SEL).
8. After completing all units in the current world, the player proceeds to the next world (NOTE: the Open Beta version of *RoboBall* has only one world).

9. After completing all worlds, the game presents a "Celebration" screen which then returns the player to the main menu.

See the subsequent Adaptive Gameplay Flow section for a visual representation of this new flow.

5.14. REVISED REWARD SYSTEM

Intific's new reward system for *RoboBall* solves two problems with the original prototype design.

- First, it integrates the game story, physics gameplay, and SEL levels.
- Second, it encourages players to finish levels in as few tries as possible. It achieves these ends by making the "treasure chest" the unit of success throughout the game.

RoboBall now begins with a "slide show" that sets up the game play conceits. Players watch as an asteroid swarm damages the Queen's cargo ship, scattering her treasure chests throughout the solar system. This introductory movie to World One furthers the story by showing the game's crew on a mission to retrieve some chests from a nebula located in deep space.

This story matches the game play goals in both the physics and SEL levels. In physics levels, players must recover chests using the game's RoboBalls. In the SEL levels, players open the chests recovered in the previous unit.

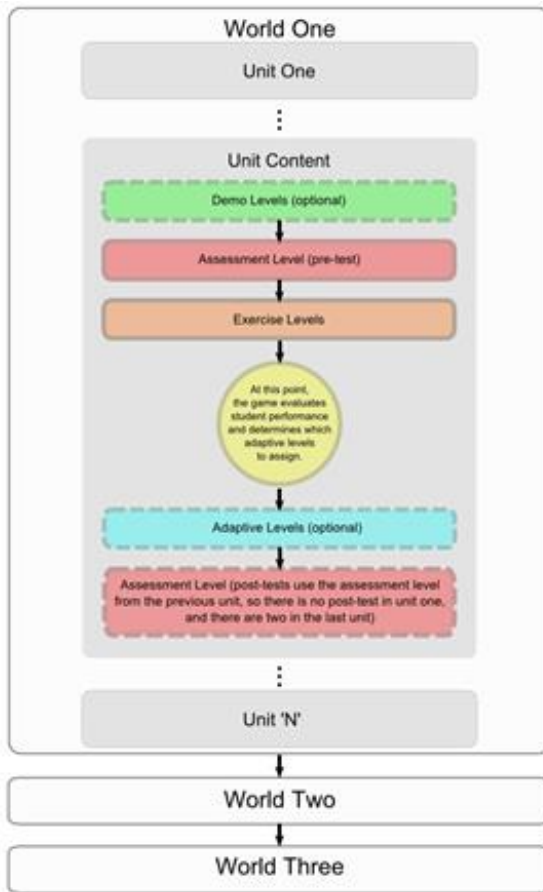
RoboBall leverages the collectible nature of the chests to discourage "trial and error" gameplay.

- At the end of each level, the game displays the number of chests so far collected in the unit.
- If players fail three times in a given unit, the game resets progress to the start of the unit, and players lose accumulated chests.
- Once the player successfully completes a unit, the game "unlocks" the chests, rewarding the player with new items on the "collectibles" screen.

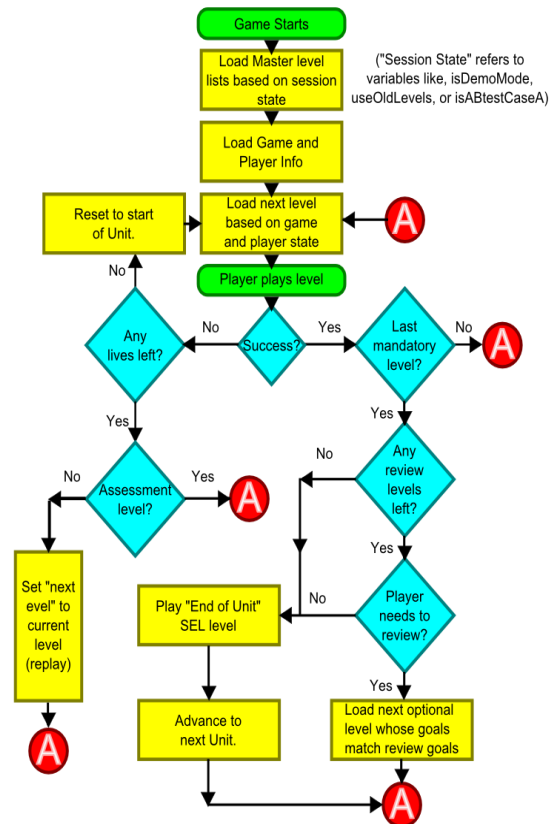
5.15. ADAPTIVE GAMEPLAY FLOW AND ADAPTIVE LEVEL FLOW

5.15.1. ADAPTIVE LEVEL FLOW ALGORITHM

The following diagrams summarize how Intific's Adaptive Level Flow Algorithm and Dynamic Level Loading Algorithm operate.



Adaptive Level Flow Algorithm



Dynamic Level Loading Algorithm

5.15.2. DYNAMIC LEVEL LOAD SYSTEM

This section discusses the *OurSpace* engine's Dynamic Level Loader, its use cases, and its architectural requirements, evolved during Phase II engineering efforts.

2.1.1.1. OVERVIEW

OurSpace has a dynamic level loader that allows learning games to load different types of content based upon the current game state.

"Game state" refers to a combination of variables that may come from the portal from which the game was launched, the game itself, or the current user's profile.

Example: Student 153 launches the latest version of RoboBall. Student 153 intends to continue her game from its last save point. She has been struggling with the game recently, and the adaptive content algorithm has determined she needs extra help with the current learning target. When the game starts, the dynamic level loader checks her current learning goals in order to choose the next appropriate level.

USE CASES

At a minimum, the dynamic level loader was required to support the following modes of operation:

1. Serve up a set of demo levels
2. Serve up levels in a dynamic order based on game state (e.g., return to the last checkpoint after the player dies 3 times)
3. Serve up levels in a dynamic order based on player state (e.g., skipping content related to learning goals the student has already mastered)

2.1.1.2. *ROBOBALL*-SPECIFIC REQUIREMENTS

In the Phase II design, *RoboBall* also required the following features to support its dynamic level loading algorithm:

- Ability to store learning goals associated with a level in the level's metadata
- Ability to identify a level's "Unit Identifier" in the level's metadata
- Ability to store the level's type (Demo, Assessment, Exercise, or Adaptive) in the level metadata
- Ability to load all the metadata associated with all the levels in a given level list in a single call

2.1.1.3. REVISED LEARNING TARGETS

To support this new Adaptive design, we have also broken down the original learning targets into smaller sub-goals. The listing below shows all goals relating to the content in World 0:

LEARNING GOALS

Target M2: Students will be able to distinguish the concepts of: position and distance, time and duration, speed.

- M2-1: The larger the push or pull (impulse) acting on a body, the larger the change in the object's momentum
- M2-2: An object under constant acceleration travels faster per unit time in each subsequent time interval

Target F1: Students can demonstrate that a force is a push or pull that can change an object's position and put it into motion. **BACKGROUND:** The position and motion of an object can be changed by pushing or pulling. An object at rest will stay at rest unless a force is applied.

- F1-1: a stationary mass, when pushed or pulled, moves in the direction of the push or pull
- F1-2: CLARIFICATION – in the absence of external forces like gravity, pushes and pulls behave identically in all direction

Target F2: Students will demonstrate understanding that the more massive an object, the more force is needed to set the object into motion in the direction of the force. Mass is the amount of matter in an object. Mass is not the same as size. Force is a push or pull

- F2-1: given the same impulse, the heavier of two masses will experience a smaller change in motion
- F2-2: given two objects of equal mass, that which experiences the larger impulse will experience a greater change in motion

Target F3: Students are able to explain that forces are composed of magnitude and direction. **BACKGROUND:** Magnitude of force is its size and strength. Force always has a direction.

- F3-1 (goal 17): given two impulses at right angles to one another, students can predict the resultant direction
- F3-2 (goal 18): given two opposing impulses acting on a single mass, students correctly predict whether or not impulses cancel
- F3-3 (goal 19): given unequal masses traveling with equal speed, students understand that stopping the greater mass requires greater impulse
- F3-4 (goal 20): given equal masses traveling at unequal speeds, students understand that stopping the faster mass requires greater impulse
- F3-5: in the absence of external forces, impulses need not be applied at the same time to produce the same resultant momentum

Target G1: Gravity in one dimension

- G1-1: an object under the influence of gravity accelerates straight down
- G1-2: gravitational acceleration is independent of mass

Target G2: Gravity in two dimensions

- G2-1: gravity affects only the vertical component of motion
- G2-2: the normal force offsets gravity: the steeper the incline, the smaller the offsetting (normal)
- G2-3: constant vertical acceleration, combined with constant horizontal speed, results in parabolic trajectory force

Target Fr1: Students can identify and explain that friction manifests itself as a force, and that this force always acts in a direction opposite to that of a moving object.

BACKGROUND: An object in motion will stay in motion unless acted upon by an outside source.

- Fr1-1: friction is a force created by the interaction of two surfaces
- Fr1-2: frictional force usually opposes the motion of bodies involved
- Fr1-3: frictional force varies directly with mass, resulting in identical acceleration for objects of different weight

Target Fr2: Students can determine, in relative terms, how much friction a given surface's texture will pose to objects moving along it (a lot, a little, somewhere in between)

- Fr2-1: the magnitude of friction force depends on the surfaces involved in the interaction

2.1.1.4. WORLD 0 LEVEL PROGRESSION

This section presents the learning progression for World 0 (Force and Motion in the Absence of Gravity and Friction). The progression builds on itself, introducing a single concept with each suite. In the diagrams below, each level type is color-coded as follows:

LEVEL TYPES KEY

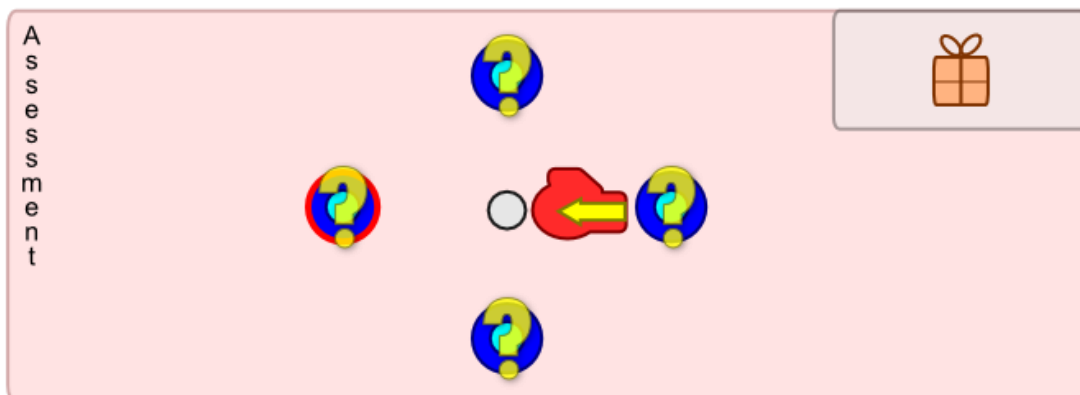
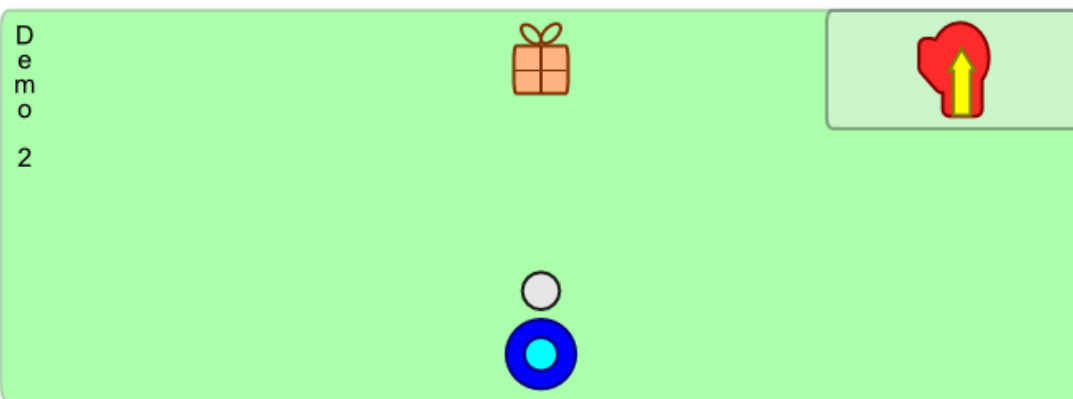
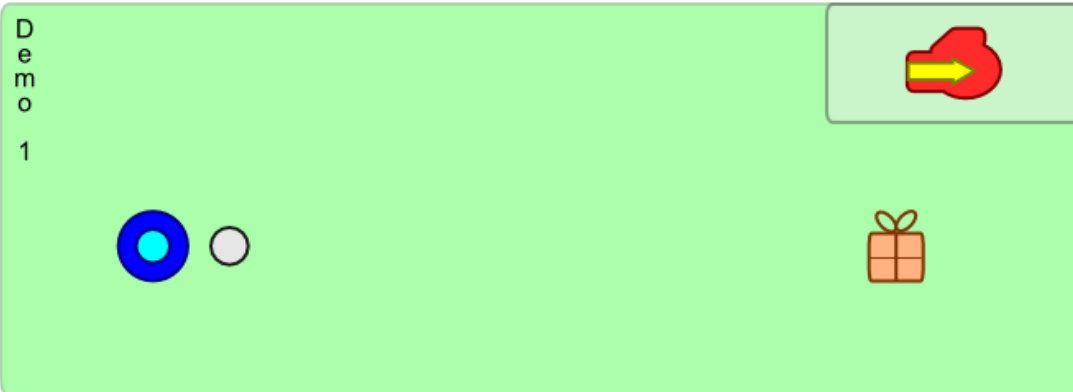
- **Demo Levels (green):** these demonstrate new game mechanics. Students cannot fail these. The game disregards data from these levels.
- **Assessment (Superstar) Levels (pink):** these present challenging problems using only previously-demonstrated mechanics. Students are allowed only one attempt to solve the level.
- **Exercise Levels (tan):** these present "normal" problems using only previously-demonstrated mechanics. These levels provide the bulk of student performance data.
- **Adaptive levels (cyan):** these are additional exercise levels that appear only if the player has performed below 80% on associated learning target

Game Progression

IMPULSE WORLD, UNIT 1

(IMAGES BEGIN ON THE FOLLOWING PAGE)

World: 0 Physical Rules: No gravity, no friction
Unit: 1 Learning Goals: F1-1, F1-2



World: 0 Physical Rules: No gravity, no friction
Unit: 1 Learning Goals: F1-1, F1-2

Exercise 1

Exercise 2

Adaptive 1

Adaptive 2

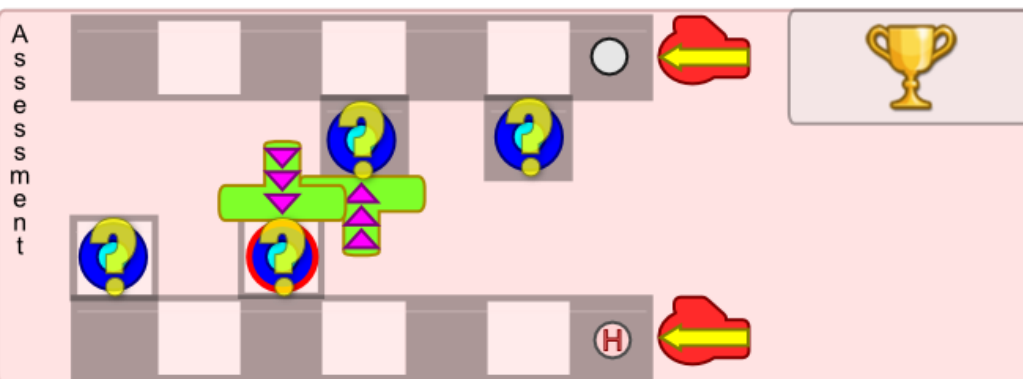
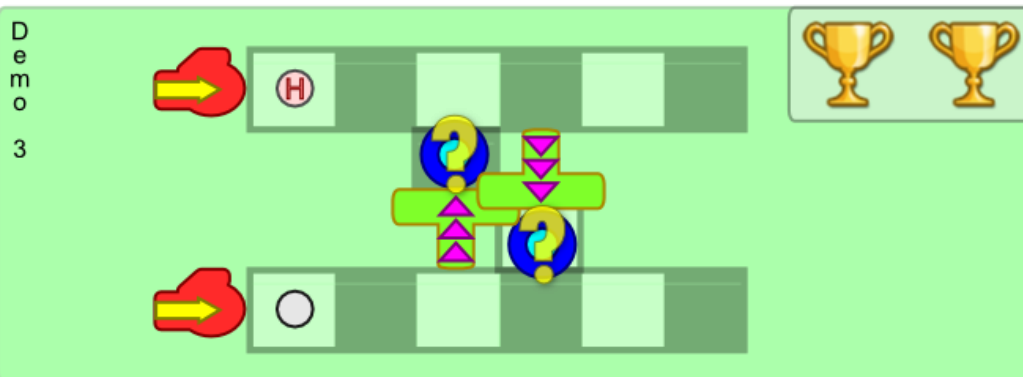
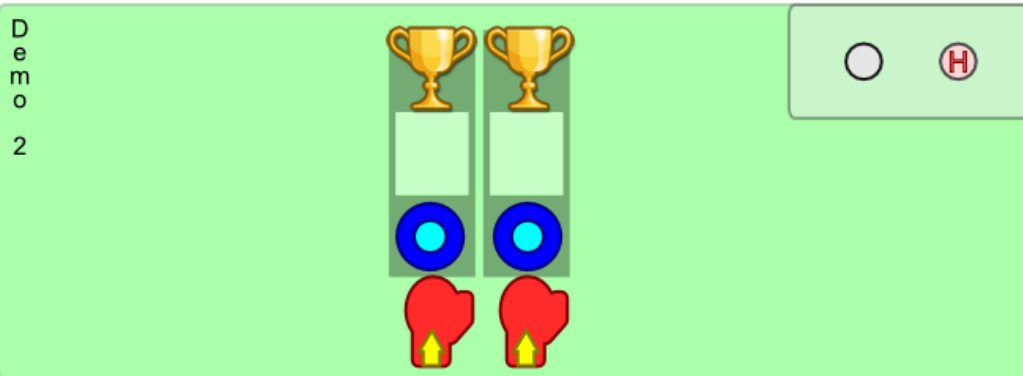
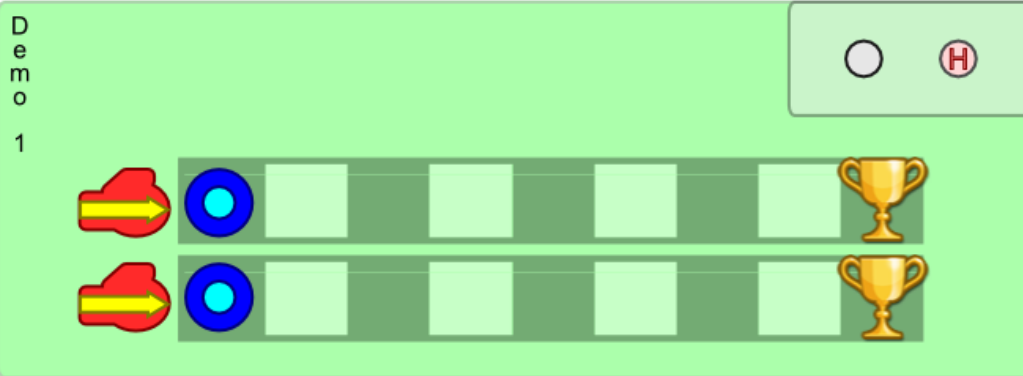
IMPULSE WORLD, UNIT 2

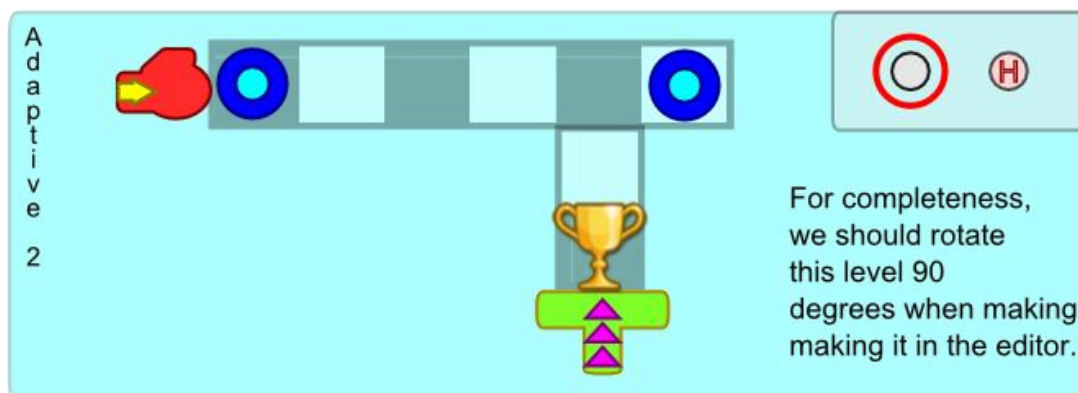
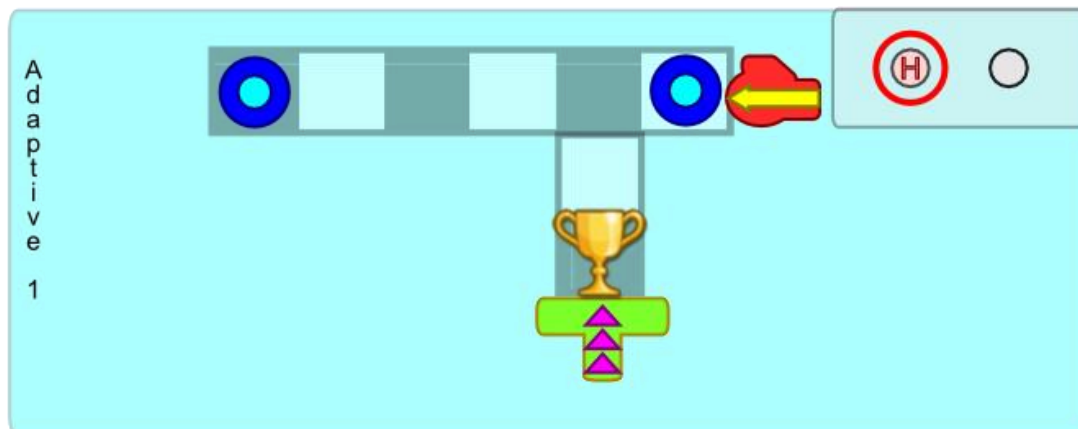
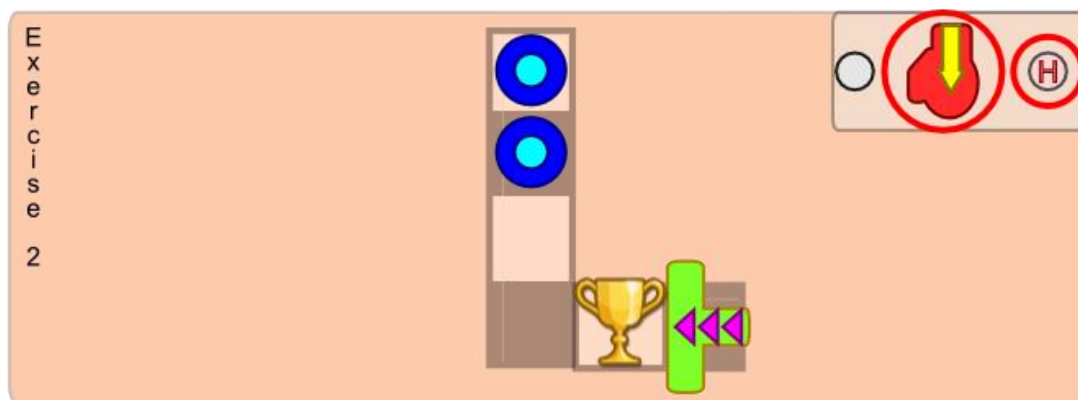
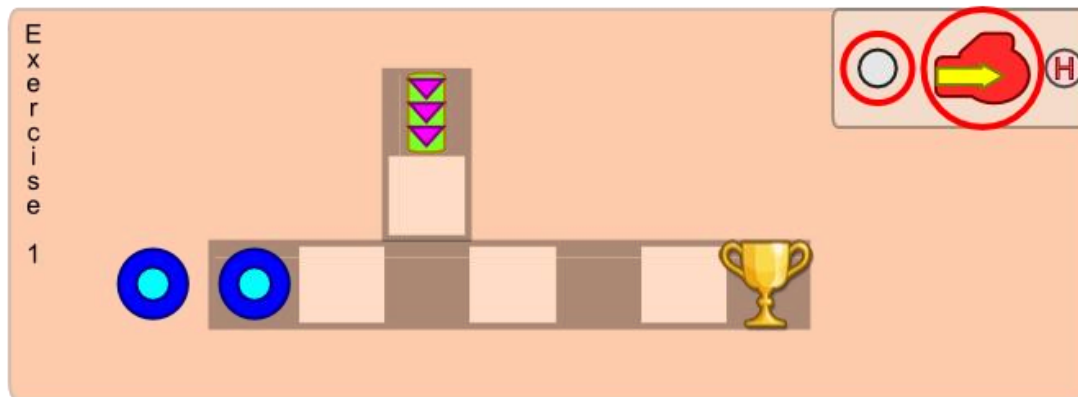
World: 0 Physical Rules: No gravity, no friction	
Unit: 2 Learning Goals: F1-1, F1-2, F2-2, M2-1	
D e m o 1	
D e m o 2	The ball should just squeak by this "blocker".
D e m o 3	The ball should just barely intersect the goal as it is pushed into the ball's path.
A s s e s s m e n t	

World: 0 Physical Rules: No gravity, no friction	
Unit: 2 Learning Goals: F1-1, F1-2, F2-2, M2-1	
E x e r c i s e 1	
Exercise 2	
A d a p t i v e 2	

IMPULSE WORLD, UNIT 3

World: 0 Physical Rules: No gravity, no friction
Unit: 3 Learning Goals: F1-1, F1-2, F2-1, M2-1





IMPULSE WORLD, UNIT 4

World: 0 Physical Rules: No gravity, no friction
Unit: 4 Learning Goals: F1-1, F1-2, F3-1

Assessment

Exercise 1

Exercise 2

Exercise 3

World: 0 Physical Rules: No gravity, no friction
Unit: 4 Learning Goals: F1-1, F1-2, F3-1

Exercise 5

Adaptive 1

Adaptive 2

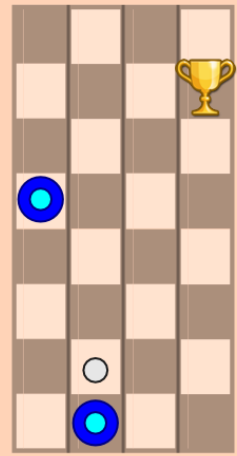
Adaptive 3

IMPULSE WORLD, UNIT 5

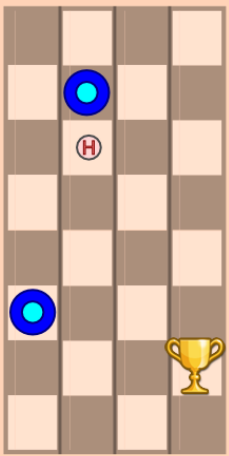
World: 0 Physical Rules: No gravity, no friction
Unit: 5 Learning Goals: F1-1, F1-2, F2-1, F2-2, F3-1, F3-5




Assessment

Exercise 1

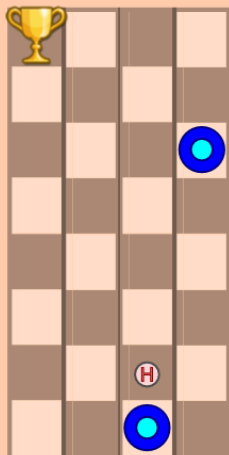



Exercise 2

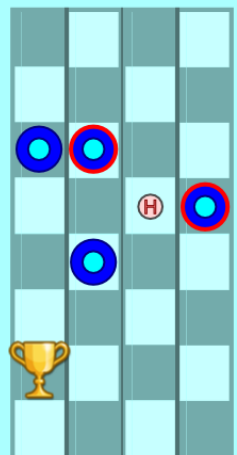



Exercise 3

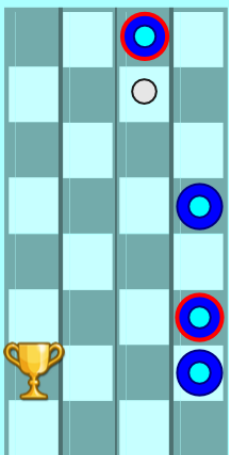
World: 0 Physical Rules: No gravity, no friction
Unit: 5 Learning Goals: F1-1, F1-2, F2-1, F3-1, F3-5

Exercise 4

Adaptive 1

Adaptive 2




Adaptive 3

IMPULSE WORLD, UNIT 6

World: 0 Physical Rules: No gravity, no friction
Unit: 6 Learning Goals: F1-1, F1-2, F2-1, F2-2, F3-2, M2-1

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World: 0	Physical Rules: No gravity, no friction
Unit: 6	Learning Goals: F1-1, F1-2, F3-2, M2-1

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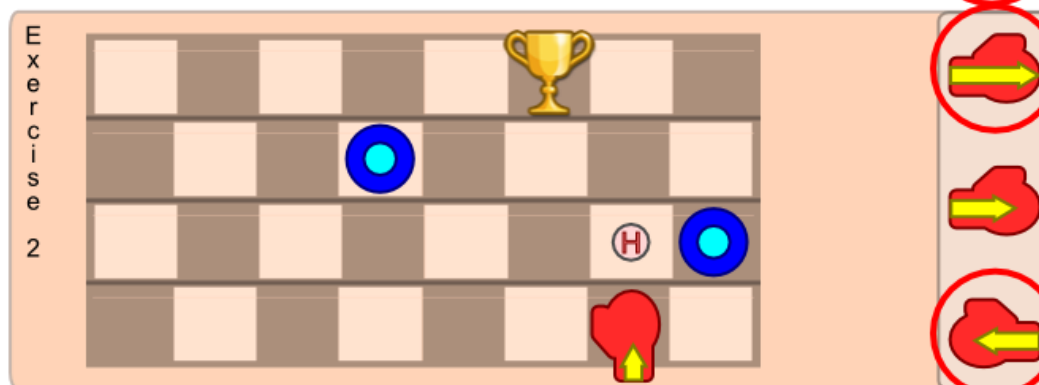
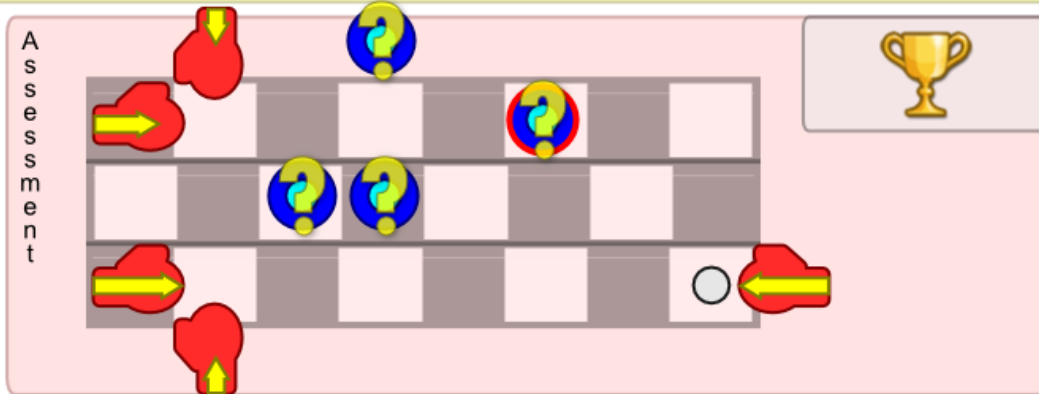
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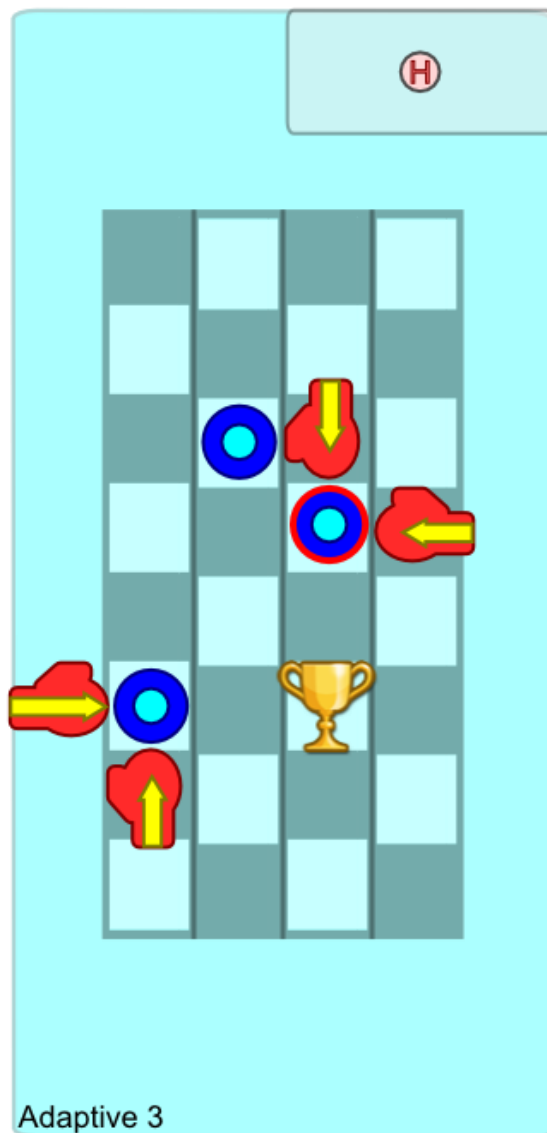
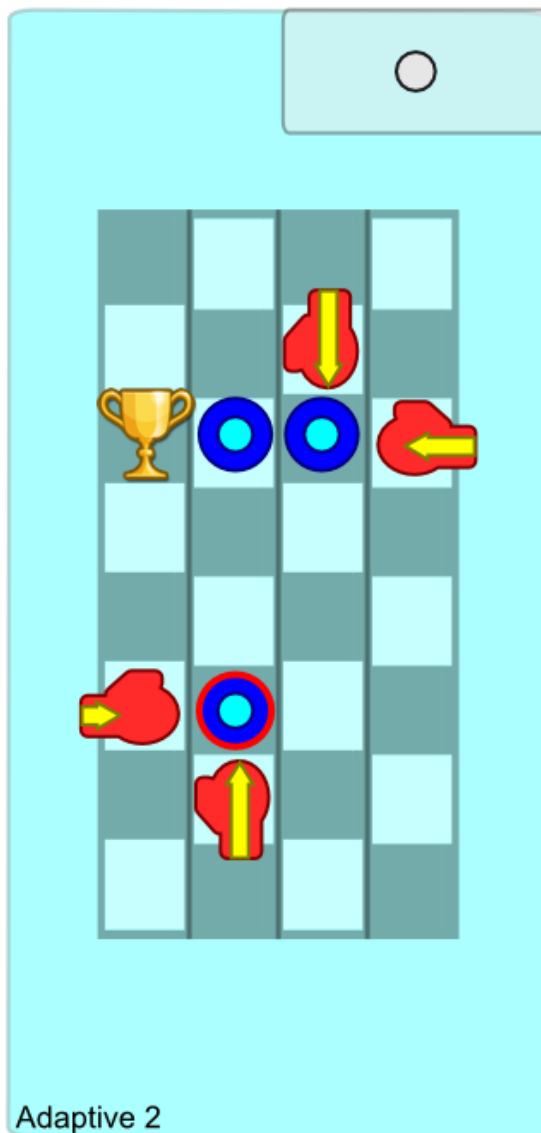
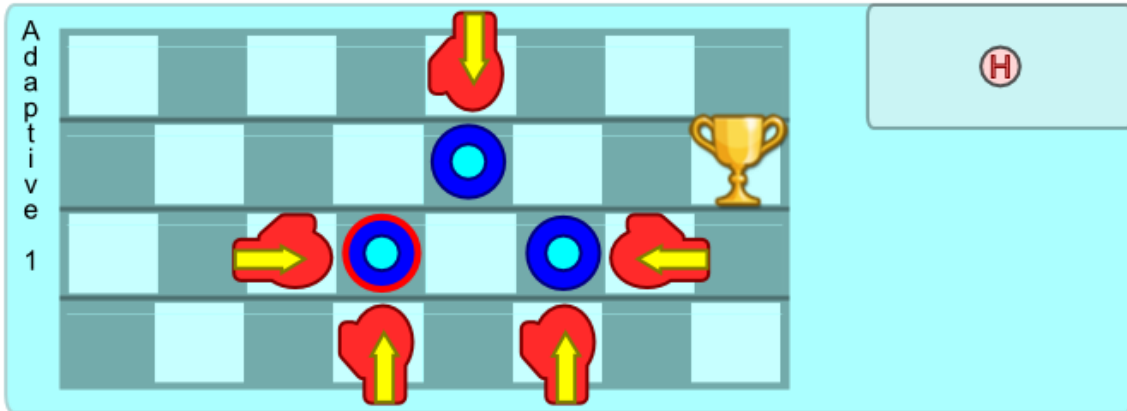
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IMPULSE WORLD, UNIT 7

World: 0 Physical Rules: No gravity, no friction
Unit: 7 Learning Goals: F1-1, F1-2, F2-1, F2-2, F3-1, F3-2



World: 0 Physical Rules: No gravity, no friction
Unit: 7 Learning Goals: F1-1, F1-2, F2-1, F2-2, F3-1, F3-2



2.1.1.5. ASSESSMENT ALGORITHM FOR ADAPTATION

The following section further describes the algorithm used to determine which Adaptive levels to assign to *RoboBall* players.

ASSESSMENT, ADAPTATION, AND LIVES

RoboBall provides two systems for managing "Adaptive Content" -- Lives and Dynamic Level Loading:

- The Lives system awards the player three "lives" at the start of each Unit
 - Failure of a level results in the loss of one life
 - Loss of all lives results in automatic reset to the first level in the Unit and the restoration of the three lives
 - This system ensures a minimum mastery of concepts before allowing players to proceed to later Units, which addresses the game's current "scaffolding" problem
- Dynamic Level Loading examines the player's performance at the end of each Unit's mandatory content
 - If the player needs additional help, the game inserts optional levels into the level flow
 - If the player needs no additional help, the game proceeds to the Unit Success screen and awards bonus Chests for unplayed content

ADAPTATION ALGORITHM

RoboBall uses the following algorithm to determine if players need additional help at the end of a Unit's mandatory content:

- At the end of a level, the game records an "attempt" for each learning target associated with that level
- The game tracks only the last 5 attempts per learning goal, represented by a circular buffer
- If the player successfully completed the level, the game records the success in another circular buffer
- At the end of the Unit's mandatory content, the game computes the player's "pass rating" (e.g., 75%) for all learning targets
- Per goal, if the "pass rating" falls below a specified threshold, the game flags that goal as a 'review subject'
- The game then assigns optional levels whose learning goals match any of the 'review subjects'

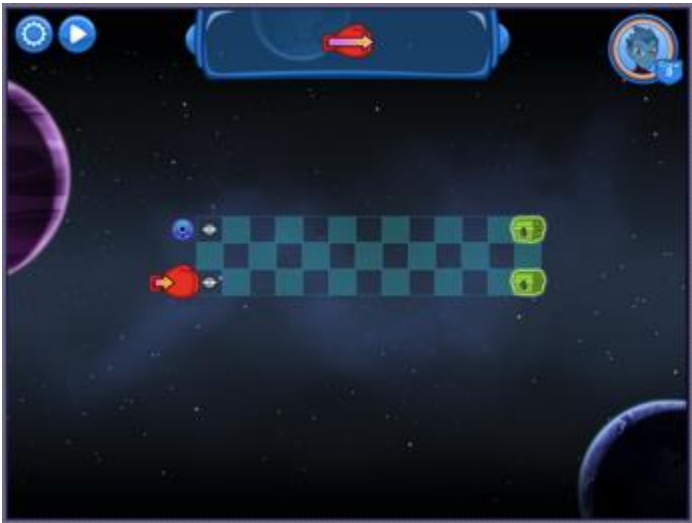
LEVEL	SCREENSHOT	NOTES
Unit 1	Objective: Adding a force (a push) so the ball will hit the treasure chest In these introductory levels, the force magnitude and mass of the ball are fixed (i.e., 'big force' and small mass ball) However, the direction of the force (e.g., horizontal or vertical) does vary, and this unit focuses on the direction of the force. Students learn that the force can change the ball's position and put it in motion.	
1-1, 1-2		1. In Level 1, the game models what to do by showing the punching glove move to the appropriate location 2. Students can only place objects in the toolbox at locations marked by this icon:  3. Instruct students to push the "play" button once they have place the object(s) in the desired locations. 4. There is only one possible answer option for the first two levels to get students acquainted to the game

		
1-3		1. Ask the student where they should place the treasure chest so the ball will hit it. If needed, remind the student that they can only place the chest on one of the blue-purple circles. 2. There are multiple potential locations for where to place the treasure chest. Student needs to understand the direction of the force (vector).

1-4,
1-5



1. Student must decide on the direction of the force needed to make the ball hit the treasure chest. Ask the student if they need to make the ball move upward or downward (or right vs. left), and which punching glove they should pick to achieve this.

Level	Screenshot	Notes
Unit 2	Objective: Unit 2 introduces the student to the concept of magnitude, which is the size and strength of the force. There are two force magnitudes in this game (i.e., big and small). Students will be able to distinguish the concepts of position and distance, and understand that there is a time component when moving from one position to another.	
2-1	 The screenshot shows a game interface with a dark space background. A red ball is positioned on a horizontal path made of alternating blue and green squares. Two arrows originate from the ball: a short red arrow pointing right and a longer blue arrow pointing right. At the end of the path are two green treasure chests. The interface includes a play button and a globe icon in the top left, and a circular menu in the top right.	1. Level introduces player to the concept of magnitude, which is the size and strength of the force. 2. Students observe and compare what happens when the ball is hit by a punching glove with a small force (i.e., shorter arrow) versus a punching glove with a big force (i.e., longer arrow) 3. Can prompt student by asking them which ball reached the treasure chest first and why they think this is the case a. Student should understand that a bigger force gets the ball to the treasure chest “faster”, and therefore reaches the treasure chest in a shorter amount of time (in comparison to the ball hit with a small force).

2-2		1. In Unit 1, students learned about direction, and this concept reappears in Unit 2. The purple arrows indicate that once the 'play' button is pushed, the objects will move in the direction of the arrows. 2. The ball cannot hit the moving comet, but must hit the moving treasure chest. 3. There is only one possible (and correct) option in this level. The student should observe and remember what happens when the ball is hit with a big force.
2-3		1. There is only one possible (and correct) option in this level. The student should observe and remember what happens when the ball is pushed with a 'small force'

2-4		1. Drawing on observations and knowledge gained from the previous levels, the student needs to place the treasure chest on the appropriate location (i.e., marker in first column) so that the ball hit with a small force will hit the treasure chest. 2. If student gets stumped, instruct them to think about what happened in the previous levels they just completed (comparing how far and how fast the ball will travel when hit with a small or big force). And, remind student that the location targets will move in the direction of the purple arrows once they hit play.
2-5		1. Student needs to select whether a small or big force is needed to get the ball to miss the comet, but hit the treasure chest. 2. Instruct student to use information from the previous levels to decide which sized force magnitude is needed. Based on the previous level (2-4), a student should know that a small force would lead the ball to hit the comet (as the placement is identical to the previous level). Therefore, the big force is the correct answer.

2-6

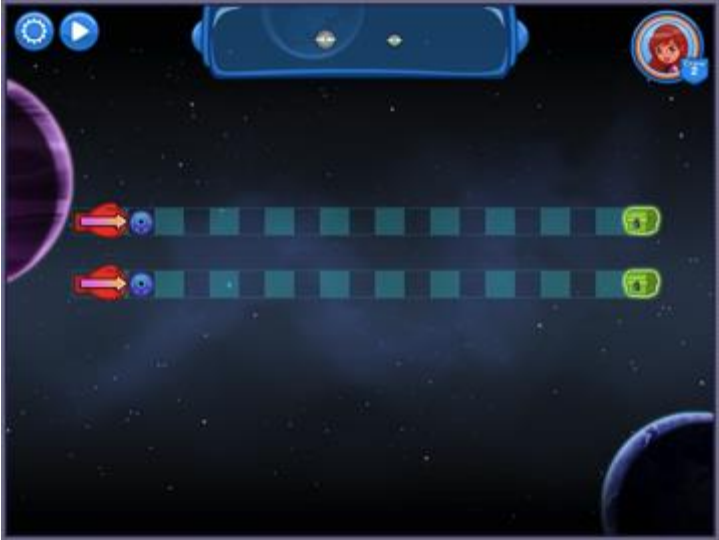


Similar to level 2-5

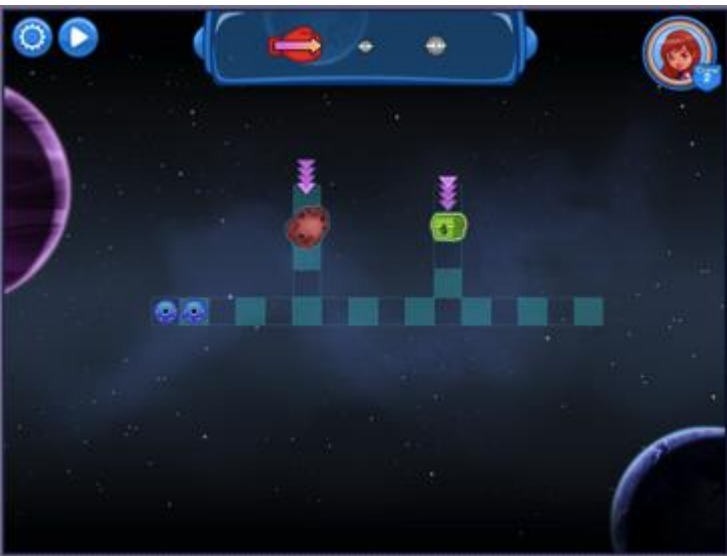
2-7



Similar to levels 2-5 and 2-6, except this time, instead of selecting the correct force magnitude, the student needs to decide where to place the ball.

Level	Screenshot	Notes
Unit 3	Objective: Unit 3 introduces the concept of mass by varying the mass of the balls (i.e., small and large mass balls) Students are also introduced to the concept of force as a vector (i.e., forces are composed of magnitude & direction). Students will be able to describe the motion of the balls addressing components of position, distance, and time and using words such as ‘faster,’ ‘slower,’ ‘more,’ and ‘less.’ Students will demonstrate understanding that for an object to accelerate at a given rate; more force is needed for objects with greater mass than for objects with lesser mass. Student will understand that when force magnitude is held constant, the ball with less mass will travel faster than the ball with greater mass.	
3-1		1. Student is able to observe and compare what happens when a big force hits a ball with greater mass versus a ball with less mass 2. Prompt students to identify which ball reached the treasure chest first, and to explain why they think this is the case a. Student should understand that the ball with less mass travels faster (than the ball of greater mass) when provided with a push of the same force magnitude

3-2		1. Player is able to observe and compare what happens when a small force hits a ball with greater mass versus a ball with less mass 2. Prompt students to identify which ball reached the treasure chest first, and to explain why they think this is the case a. Student should understand that the ball with less mass travels faster (than the ball of greater mass) when provided with a push of the same force magnitude
3-3		1. After placing the punching gloves in the designated locations, prompt students to describe and explain what happened, and why they think this is the case a. By placing both 'big force' punching gloves (vectors) in the designated locations, the student will observe that when holding force magnitude constant, the ball with greater mass will travel slower (hitting the treasure chest that is closer), and how the ball with less mass will travel faster (hitting the treasure chest that is farther away).

3-4		1. Student must identify where to place the treasure chest so that one of the balls (of greater or less mass) will hit the treasure chest 2. Students must keep in mind that the target locations will move in the direction of the arrows
3-5		1. Student must decide which ball (of greater or less mass) should be used to reach the treasure chest. 2. The ball must travel fast enough to avoid the comet and reach the treasure chest before it passes by

3-6



Levels 3-4 and 3-5 are similar to levels 3-6 through 3-8

3-7		Levels 3-4 and 3-5 are similar to levels 3-6 through 3-8
3-8		Levels 3-4 and 3-5 are similar to levels 3-6 through 3-8

Level	Screenshot	Notes
Unit 4	Objective: Students will learn that resultant forces arise when two or more forces in different directions are added together, and that when applied to an object, the object's resulting direction of motion and rate of acceleration will be determined by the magnitude and direction of motion of the resultant (net) force applied. Student should also learn that when: • Horizontal force > Vertical force → Object's path is closer to X-axis • Horizontal force = Vertical force → Object's path follows a 45° angle • Horizontal force < Vertical force → Object's path is closer to Y-axis Unit 4 game play should dispel the misconception that the motion of an object is always determined by the last force applied to it.	

4-1



- Student must decide where to place the treasure chest based on the projected path of the ball given the resultant net force applied
- Student needs to understand:
Horizontal force < Vertical force → Object's path is closer to Y-axis



Q: What will happen if we just give the ball a big force this way (going down)?

A: Ball will move straight down.

Now, this glove is also going to give the ball a **small force** this way (going left). Let's say, since it is a **small force**, it is going to push it over **one square**.



And since this glove gives a **big force**, it will push the ball over **two squares**.



So imagine, ball goes down for **two** squares, and boom, **one** small square this way. Then **two** big squares down, and boom, another **one** small square this way.

Which target will the ball hit?



4-2



- Student must decide which vectors are needed (and where they should be placed) in order to ensure that the ball hits the treasure chest.
- Student needs to understand:
Horizontal force > Vertical force → Object's path is closer to X-axis

4-3



- Student must decide which vectors are needed (and where they should be placed) in order to ensure that the ball hits the treasure chest.
- Student needs to understand:
Horizontal force = Vertical force $\rightarrow$ Object's path follows a 45° angle

The only glove that points to the left will give a **small force**. Again, let's say that since it is a **small force**, it is going to push it over **one square**.



Let's see what happens if we use a **small force** in the up direction.



Let's see what happens if we use a **big force** in the up direction.



4-4



- Student must decide which vectors are needed (and where they should be placed) in order to ensure that the ball hits the treasure chest.
- Student needs to understand:
Horizontal force = Vertical force $\rightarrow$ Object's path follows a 45° angle

4-5



- Student must decide where to place the treasure chest based on the projected path of the ball given the resultant net force applied
- Student needs to understand:
Horizontal force < Vertical force → Object's path is closer to Y-axis

4-6



- Student must decide where to place the ball to ensure that the ball hits the treasure chest. Needs to understand which net force will place the ball on the correct trajectory
- Student needs to understand:
Horizontal force = Vertical force $\rightarrow$ Object's path follows a 45° angle

4-7



- Student must decide where to place the ball to ensure that the ball hits the treasure chest. Needs to understand which net force will place the ball on the correct trajectory
- Student needs to understand:
Horizontal force > Vertical force → Object's path is closer to X-axis
(answer is top location; the bottom location would require = forces to create a 45-degree pathway to hit the treasure chest)

4-8		• Student must decide which vectors and net force is needed to ensure that the ball hits the treasure chest. • Student needs to understand: Horizontal force > Vertical force → Object's path is closer to X-axis
Level	Screenshot	Notes
Unit 5	Objective: In Unit 4, two forces were provided simultaneously. In contrast, in Unit 5, forces are provided sequentially (one after the other) in most cases. Similar rules still apply: • Horizontal force > Vertical force → Object's path is closer to X-axis • Horizontal force = Vertical force → Object's path follows a 45° angle • Horizontal force < Vertical force → Object's path is closer to Y-axis	

	Game play should dispel the misconception that the motion of an object is always determined by the last force applied to it.
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5-1		• Student must decide where to place the treasure chest based on the projected path of the ball given the resultant net force applied • Student needs to understand: Horizontal force < Vertical force → Object's path is closer to Y-axis
5-2		• Student must decide which vectors and what net force is needed to ensure that the ball hits the treasure chest. • Student needs to understand: Horizontal force = Vertical force → Object's path follows a 45° angle

5-3		• Student must decide which vectors and what net force is needed to ensure that the ball hits the treasure chest. • Student needs to understand: Horizontal force > Vertical force → Object's path is closer to X-axis
5-4		• Student must decide which vectors and what net force is needed to ensure that the ball hits the treasure chest. • Student needs to understand: Horizontal force = Vertical force → Object's path follows a 45° angle • As in Unit 4, vectors are applied to ball simultaneously

5-5



- Student must decide which vectors and what net force is needed to ensure that the ball hits the treasure chest.
- Student needs to understand:
Horizontal force = Vertical force $\rightarrow$ Object's path follows a 45° angle

- Student needs to understand:
Horizontal force = Vertical force $\rightarrow$ Object's path follows a 45° angle

5-6

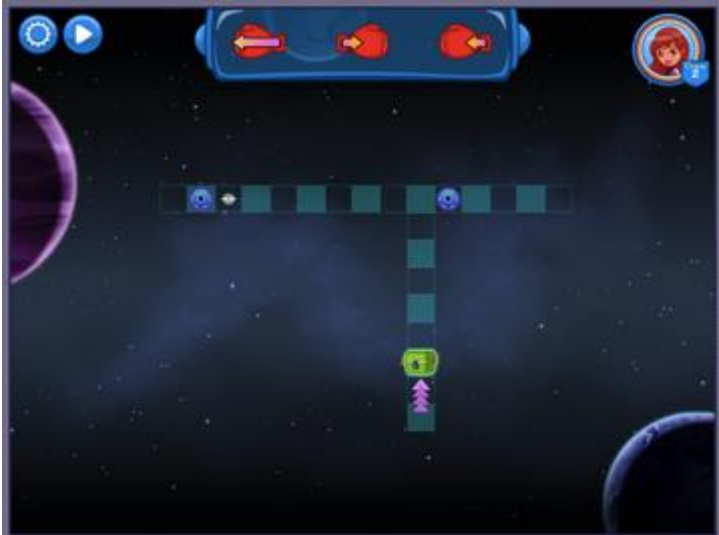


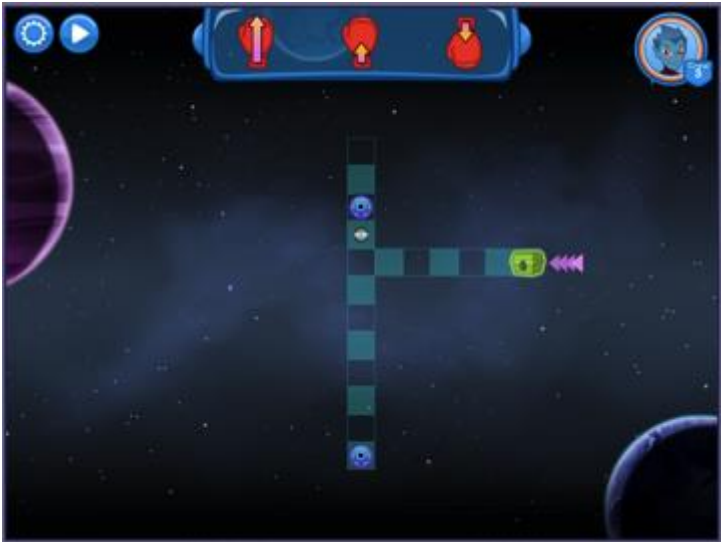
- Student must decide which vectors and what net force is needed to ensure that the ball hits the treasure chest.
- Student needs to understand:
Horizontal force < Vertical force → Object's path is closer to Y-axis

- Student needs to understand:
Horizontal force < Vertical force → Object's path is closer to Y-axis

5-7		• Student must decide which vectors and what net force is needed to ensure that the ball hits the treasure chest. • Student needs to understand: Horizontal force > Vertical force → Object's path is closer to X-axis
5-8		• Student must decide which vectors and what net force is needed to ensure that the ball hits the treasure chest. • Student needs to understand: Horizontal force < Vertical force → Object's path is closer to Y-axis

Level	Screenshot	Notes
Unit 6	Objective: Introduces two opposing forces (forces in the opposite direction) Students will be able to describe the motion of the balls addressing components of position, distance, and time and using words such as ‘faster,’ ‘slower,’ ‘more,’ and ‘less.’ Student needs to think about the timing and how fast the ball will move when hit with differing vectors. Game play should dispel the misconception that the motion of an object is always determined by the last force applied to it.	
60 10		• In levels 6-1 to 6-7, the student must decide where to place the treasure chest in order to ensure that the ball hits the treasure chest. Student needs to think about the timing and how fast the ball (of small or large mass) will move when hit with differing vectors.

6-2		
6-3		

6-4	 A screenshot from the game 'OurSpace' showing a vertical path of alternating green and dark green squares. A green arrow points right from the top of the path. The background is a dark space with a purple planet on the left and a blue planet on the right. The top interface shows a blue bar with three red icons (a person, a lightbulb, and a person) and a blue play button icon on the left. A blue circular icon with a person's face is on the right.	
6-5	 A screenshot from the game 'OurSpace' showing a horizontal path of alternating green and dark green squares. A green arrow points left from the right end of the path. The background is a dark space with a purple planet on the left and a blue planet on the right. The top interface shows a blue bar with three red icons (a person, a lightbulb, and a person) and a blue play button icon on the left. A blue circular icon with a person's face is on the right.	

6-6		
6-7		

Level	Screenshot	Notes
Unit 7	Objective: Introduces a sequence force combinations (with some involving simultaneous forces) - opposing forces (forces in the opposite direction) Students will be able to describe the motion of the ball as equal forces cancel each other out and prevailing forces push the ball along. Student needs to think about how fast the ball will move when hit with differing vectors, and determine if the next force that acts upon the ball will redirect it or stop it. Game play should dispel the misconception that the motion of an object is always determined by the last force applied to it.	

7-1		• Trajectory of ball creates a 'square-like' motion in which the ball first hits the gloves in the bottom left-hand corner, and is then bounced up towards the upper left-hand corner, and then hit in a horizontal direction towards the farthest right target location.
7-2		

7-3		
7-4		

7-5



7-6



7-7	 A screenshot from the game 'OurSpace'. The central focus is a green and black checkered chessboard floating in a dark space environment. Several chess pieces are visible: a red king, a blue king, a red pawn, a blue pawn, and a green knight. A red arrow points from the red king towards the blue king. In the top left corner, there are two blue circular icons: one with a play button symbol and another with a target symbol. In the top right corner, there is a circular icon showing a character's face. The background features a large purple planet on the left and a blue planet on the right.	
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5.15.3. GAME REVISION HISTORY

Intific's ENGAGE Game Revision History					
Deliverable	Defining Features	Physics Levels	SEL Levels	CRESST Tested	Notes
Closed Alpha - March 2013	Updated External Portal - OurSpace Converted Flash prototype levels to html5	35	1	YES - 80 students	The updated OurSpace portal enabled CRESST and our developers to use the same site for testing, data collection and level editing.
Closed Beta - May 2013	Converted Art to modular pieces Improved Log files Improved Frame Rate Improved Editor Functionality	83	6	NO - CRESST did not test this version of the game.	Making the art pieces modular enabled our developers to increase their level editing productivity. It also allowed us to iterate on our designs more rapidly.
Open Beta - Sept 2013	Adaptive Learning Integrated Pre and Post Test Assessments Improved Warning/Error Messaging Award System Improved Physics Determinism Added Storyboard Intro Movies	52	6	YES - 41 students	The adaptive learning design and the integrated pre and post tests are the hallmark of what the research version of our game is based on. With these features external research agencies can easily collect efficacy and assessment data.
Final Build - Feb 2014	Improved Warning/Error Messaging Scaled Server Solution (Amazon Server) Increased Frames Per Second from 30 to 60	52	6	YES - 20 students	Scaling our server solution allowed us to support a larger user base. This improvement enabled us to support thousands of users instead of hundreds.
SpaceForce - March 2014	Public Facing Version of the Game Partnered with BrainPOP Revised User Interface for BrainPOP's audience	52		NO - Available to the public.	Our partnership with BrainPOP has allowed us to transition our game from a research project to a consumer product. Thousands of students play it every day.

Figure 1.0 – *OurSpace* game revision history diagram

5.15.4. CONFERENCES

During Phase 2 the Intific team attended several education conferences. The reason for this was two-fold; social networking and showcasing our first *OurSpace* product. Below is a list of conferences with highlights from each event.

DARPA I20 Demo Day at the Pentagon

The Demo Day at the Pentagon was an opportunity for DARPA to showcase its Innovation and Information Offices work. There were 29 Programs represented at the demo day with well over 100 exhibits. There were one to two thousand uniformed and civilian attendees from the Pentagon who walked around the courtyard to look at each DARPA project. Intific had at least 100 people stop by to discuss the game and find out what it was about and where they could play it. We passed out information and gave many demos. A member of the press from a tech magazine interviewed Col. Ragsdale and a member of the Intific team. He also played the game for several minutes. He was taking notes and took some contact information and a handout. There may be an article released about our game. Many parents and former teachers were very excited about what we're doing. Even military personnel liked our approach to getting kids excited about learning; by developing compelling and highly interactive educational games. The event was a great success for our team.

During the event we also met a few partners that we work with on other DARPA programs such as ABM on the DCAPS Program. We also got a chance to speak with other ENGAGE program performers; Carnegie Mellon University, University of Washington and our TA-2 partner; CRESST. The event was a great opportunity to meet people working on similar products in the same field.

CRESST Center for Advanced Technology in Schools conference (CATS)

On April 29-30, 2014, Dr. Amy Kruse attended the CRESST Center for Advanced Technology in Schools conference. Dr. Kruse represented the Intific education efforts interacting with the hundreds of participants, including our CRESST colleagues. Dr. Kruse presented a Teddy Talk on the future of education games, particularly those influenced and inspired by neuroscience research. Dr. Kruse also demonstrated the Intific SpaceForce game to the conference attendees, directing them both to the new KADDEO education page and the BrainPOP Jr. sites. The response was enthusiastic and many educators in attendance were excited about both the existing games and the architecture built by the DARPA ENGAGE program. Follow up from the meeting will include new funding and teaming opportunities within the educational research and development area.

STEM Symposium

We had the opportunity to participate in a STEM Symposium in Northern VA in April 2014. Thousands of kids (and some type-A parents) showed up to talk about education and interact with our games.

We wish we had video – watching students PLAY the game and react to it... truly awesome. I couldn't have been more proud! Most of the day there was a LINE to play ... The game was EQUALLY popular with boys and girls. And some really tiny kids made great progress. It was also neat to see the adaptive aspect in play – you could tell when a student hadn't gotten the concept!

There were actually some parents that had to DRAG their kids away from playing it ("Just one more sector, mom, I'm almost done...")

South by South West Education conference (SXSWedu)

On March 4th and 5th we joined BrainPOP at the South by South West Education conference. During our presentations we discussed the game development process used at Intific and spoke about the research and planning that goes into developing an educational game for DARPA. At the conference we demoed our game and handed out updated one-sheets and activity books. We received a lot of compliments on how professional our game looks. Many people wanted to know what technology we used to build the game. They were impressed when we told them that we developed the engine ourselves.

Texas Computer Education Association conference (TCEA)

On February 5th and 6th Intific attended the Texas Computer Education Association conference (TCEA) with BrainPOP. At the conference we showcased our game and discussed the educational game development process that we use at Intific. We handed out one-sheets

containing information about the ENGAGE program and our educational game. We received many positive comments about the professional quality of the game. Our development team is proud of how far this product has come over the past couple of years.

5.16. ROBOBALL DATA COLLECTION

This section summarizes the changes in *RoboBall* that are relevant to data collection and analysis efforts. Included are breakdowns of the features added to the final software deliverable to facilitate efficacy and assessment tests. They are as follows: new game structure, new testing methods, new player incentives. Please see the *RoboBall* Open Beta Documentation FINAL for more detail (included in Final Documentation Deliverable Package).

5.16.1. NEW GAME STRUCTURE

RoboBall Open Beta is divided into "Units" that cover specific learning targets, and the units are subdivided into level groups with different pedagogical aims. The new level types are:

1. **Demo Levels** -- these introduce new game mechanics and have only one possible configuration.
2. **Exercise Levels** -- these levels pose new physics problems in their simplest form.
3. **Adaptive Levels** -- additional "exercise" levels that frame previous problems in new ways. Students will only see adaptive levels if they have failed more than 20% of the exercise levels for a given set of learning goals.
4. **Assessment Levels** -- please see "New Testing Methods" below for details about this level type.
5. **SEL Levels** -- the "social and emotional learning" levels from the earlier version of *RoboBall*.

Please see above for a listing of all units, the levels that comprise them, and the learning targets associated with each. Currently, we're not logging the level type, but we could add this.

5.16.2. NEW TESTING METHODS

As mentioned above, Intific has introduced "Assessment Levels" to gauge student learning in a crowd-sourced environment. Students play each assessment level twice: first, as a pre-test before exposure to a new concept; second, after completing all the exercise and adaptive levels relevant to the new concept. We have tried to place at least seven levels between each pre- and post-test to prevent students from answering from memory. We have added a field to the logs to indicate when the student is playing an assessment level.

5.16.3. NEW PLAYER INCENTIVES

We also introduced two player incentives to combat success through "trial and error." The first is "lives." The player starts each unit with 3 crew members. Each time the player fails a level, another crew member "sits out." When all members have failed, the game restarts at the

beginning of the unit. This mechanic feeds into the "prizes" system, which rewards players for success. Each time the player completes a level, he or she earns the chests recovered in that level. Recovered chests remain locked until the player completes the SEL level at the end of the unit. At that point, the game unlocks the chests, adding new "stickers" to the collectibles screen.

6. EXTENSION OF THE OURSPACE GAME APPROACH

As noted earlier, *OurSpace* is a broad and ambitious vision for new types of digital learning. The data collection, crowdsourced verification, and adaptability tool approach of these systems can permit a broad extension of this concept beyond the *RoboBall* force, motion and gravity learning games. This sections explores some of the exciting opportunities before us in the near future.

Intific is aggressively exploring future opportunities to expand these technologies and welcomes the opportunity to also develop future applications of these approaches in the STEM and SEL domains.

6.1. HOW TO INTEGRATE ROBObALL INTO THE CLASSROOM

The concepts developed in *RoboBall* can also be coupled with both science and mathematics curriculum. *RoboBall* maps onto the Next Generation Science Standards (NGSS) (NSF, 2013). The game mechanics in *RoboBall* are consistent with the *Performance Expectations* contained in Table 4, covers the NGSS *Disciplinary Core Ideas* contained in Table 5, and requires the use of the *Science and Engineering* practices contained in Table 6.

Table 1

NGSS Performance Expectations Related to RoboBall

Performance Expectations	
K-PS2-1	Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object.
K-PS2-2	Analyze data to determine if a design solution works as intended to change the speed or direction of an object with a push or a pull.
3-PS2-1	Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.
MS-PS2-2	Plan and conduct an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

Table 2NGSS Disciplinary Core Ideas covered in *RoboBall*

Disciplinary Core Ideas		Related Performance Expectations
Forces and Motion	Pushes and pulls can have different strengths and directions.	K-PS2-1 K-PS2-2
	Pushing and pulling on an object can change the speed or direction of its motion and can start or stop it.	K-PS2-1 K-PS2-2
	Each force acts on one particular object and has both strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on the object. Forces that do not sum to zero can cause changes in the object's speed or direction of motion.	3-PS2-1
	The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change.	MS-PS2-2
Energy	The faster a given object is moving, the more energy it possesses	K-PS2-1 K-PS2-2
Defining Engineering Problems	A situation that people want to change or create can be approached as a problem to be solved through engineering. Such problems may have many acceptable solutions	K-PS2-1 K-PS2-2

Table 3NGSS Performance Expectations Related to *RoboBall*

Related Science and Engineering Practices
Asking Questions and Defining Problems Asking questions and defining problems in grades 3-5 builds on grades K-2 experiences and progresses to specifying qualitative relationships/ • Ask questions that can be investigated based on patterns such as cause and effect relationships. • Define a simple problem that can be solved through the development of a new or improved object or tool.

Planning and Carrying out Investigations

Kindergarten. Planning and carrying out investigations to answer questions or test solutions to problems in K-2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions.

- With guidance, plan and conduct an investigation in collaboration with peers.

3rd grade. Planning and carrying out investigations to answer questions or test solutions to problems in 3-5 builds on K-2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.

- Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials are considered.
- Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution.

Analyzing and Interpreting Data

Analyzing data in K-2 builds on prior experiences to collecting, recording, and sharing observations.

- Analyze data from tests of an object or tool to determine if it works as intended.

In the domain of mathematics, *RoboBall* is aligned with three *Common Core State Standards*:

1. Reason abstractly and quantitatively.
2. Describe measurable attributes of objects, such as length or weight. Describe several measurable attributes of a single object.
3. Directly compare two objects with a measurable attribute in common, to see which object has “more of” / “less of” the attribute, and describe the differences.

6.2. RELATED FORMATIVE ASSESSMENT PROBES (KEELY & HARRINGTON, 2010)

The following are additional recommended considerations that the game system could support.

- Is it possible to make the ball roll at a constant speed (i.e., when the ball is neither slowing down nor speeding up)?
- What is a force?
- Present students with common misconceptions about force and motion and ask them to explain their thinking about those ideas.
- How would someone walk to school if there were no friction in the world?

6.3. RELATED “REAL-WORLD” EXAMPLES

Common hands-on exercises that can also be used to accompany *RoboBall* gameplay include the following:

- Measure the distance and/or the time it takes for various objects (cars, balls, boxes, blocks) to travel along different surfaces.

- Have students walk side by side at different speeds while dropping a rock on the ground at steady intervals. Examine the differences in the ‘rock trails’ left by each student.
- Have students generate examples of difference things that exert a force or are acted upon by forces. Use those examples to go on a “forces scavenger hunt”.
- Have young children push or pull on objects using their own muscles.
- Play *RoboBall* charades by giving students a scenario depicted in one of the levels of *RoboBall* and having kids act it out.

6.4. SOCIAL EMOTIONAL LEARNING GOALS OF ROBOBALL

SEL concepts covered in *Roboball* are emotional awareness (i.e., emotion knowledge/recognition) and perspective-taking. Specific learning objectives would let students recognize and label (i.e., identify) own and other’s emotions based on facial, nonverbal, behavioral and contextual cues.

6.5. HOW ROBOBALL CAN BE USED IN THE CLASSROOM

This game can be coupled with a math and science curriculum because the SEL components of the game reinforce students’ ability to understand other student’ perspectives, and thereby contributes to more effective collaboration and group problem-solving among students which are foundational skills required to effectively solve and understand many math and science problems, especially when working with peers.

6.6. REAL-WORLD EXAMPLES THAT THIS GAME RELATES TO

Common hands-on SEL exercises for the classroom that relate to *RoboBall* could include prompting students to engage in emotion recognition and perspective-taking skills if disagreements or conflicts arise among peers. For instance, if two students are stuck because they are disagreeing about how to proceed with a science problem or with their approach to solving a math problem, the students can be prompted to stop and assess how they think the other student is feeling and why.

Once students realize that they are experiencing specific emotions based on their experience, and that these emotions are making it difficult for them to continue with their task; they can be further prompted to come up with a solution or response that will help them feel better. The decision the students make with respect to how to make the other student feel better, will help both of the students proceed with the task, as they will be taking the perspective of the other student into account when making their decisions.



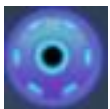
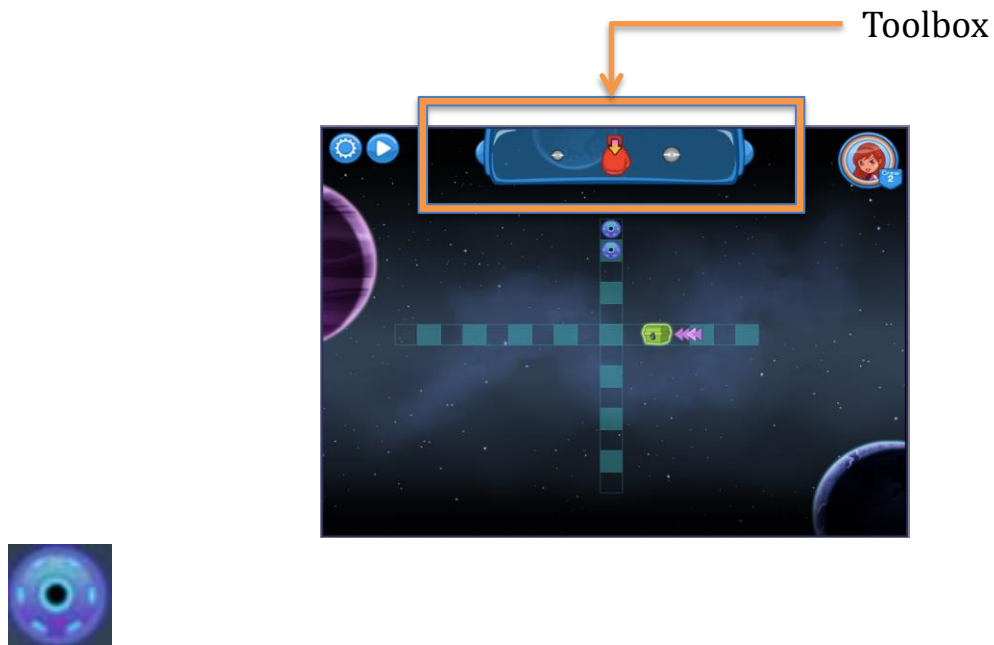
6.7. BASIC GOAL AND MECHANIC OF THE GAME:

The goal is for the vector(s) to hit the ball, and then for the ball to hit the treasure chest

Players must place the force arrow(s) (i.e., vectors), ball(s), and/or treasure chest(s) in the appropriate location(s) to achieve this goal

6.8. INSTRUCTIONAL HELP

Players will select objects from the toolbox and place them in the appropriate locations by clicking and dragging. Then player will push the “play” button.

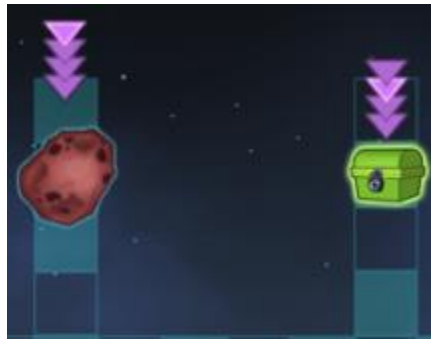


Objects (e.g., vectors, balls, treasure chests) can only be placed on locations this graphic marks.

6.9. REPRESENTATIONAL CUES

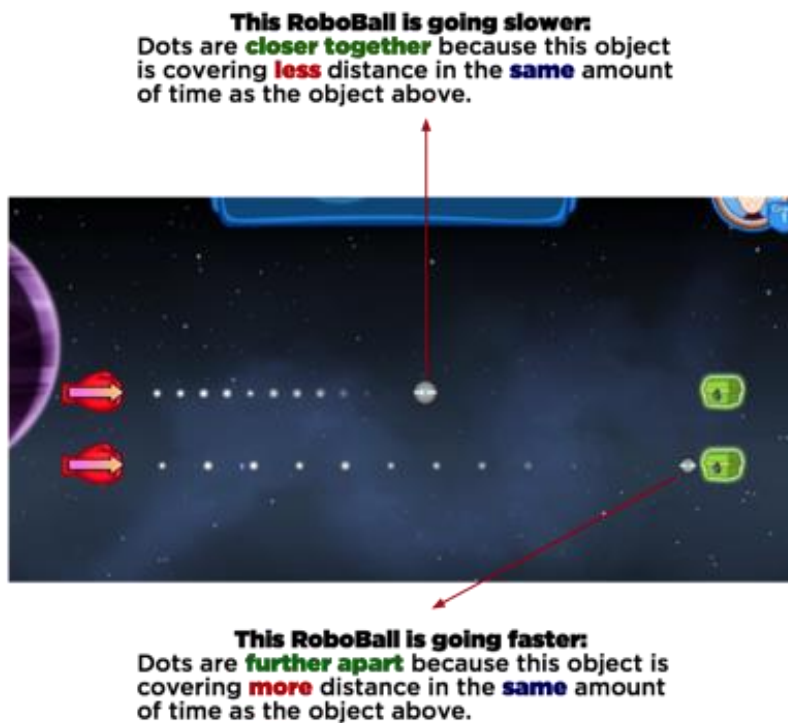
In *RoboBall*, our game developers used icons and animations to help convey underlying concepts.

Direction and Speed: Purple arrows indicate that the object(s) will move in that direction once the ‘play’ button is pushed. They also indicate the object’s speed.



The ball cannot hit the comet(s), but must hit the treasure chest.

Speed: The balls leave behind bread crumb trails that indicate their speed:



6.10. FORCE MAGNITUDE

In this game, there are **two** possible **force magnitudes**:

(In introductory levels, only one fixed force magnitude will be present. However, in later levels, the



player may need to choose the correct option)

Small force magnitude – indicated by short arrow



Large force magnitude – indicated by long arrow

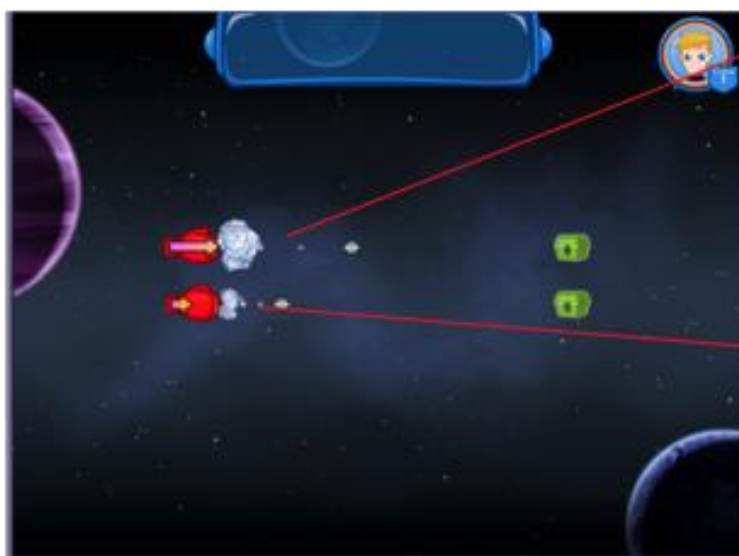
When the RoboBalls are hit, they also give off a puff of smoke on impact. When the same force magnitudes are used, the sizes of the puff of smoke are the same.

These RoboBalls were given the same size force:

Both of the RoboBalls were given big size punches so the 'force puff' should be the **same** size.



When you use different force magnitudes the size of the smoke effects differ too.



Large Force Magnitude

Depicted by the **big** puff of smoke.

Small Force Magnitude

Depicted by the **small** puff of smoke.



Vectors may be oriented in the following **directions**:

(In some levels, direction may be fixed. However, in some levels the player may need to choose the correct option)

In this game, there are **two** possible **ball masses**



(In introductory levels, only one fixed mass will be present. However, in later levels, the player may need to choose the correct option)

6.11. A NEW SPACEFORCE VERSION OF ROBOBALL

6.11.1. BRAINPOP JR., REDESIGN OVERVIEW

This section details changes to *RoboBall*'s design in response to feedback from BrainPOP, Jr. This design restricted certain features due to the absence of persistent user IDs. These changes are denoted with an asterisk *.

BrainPOP's changes are as follows:

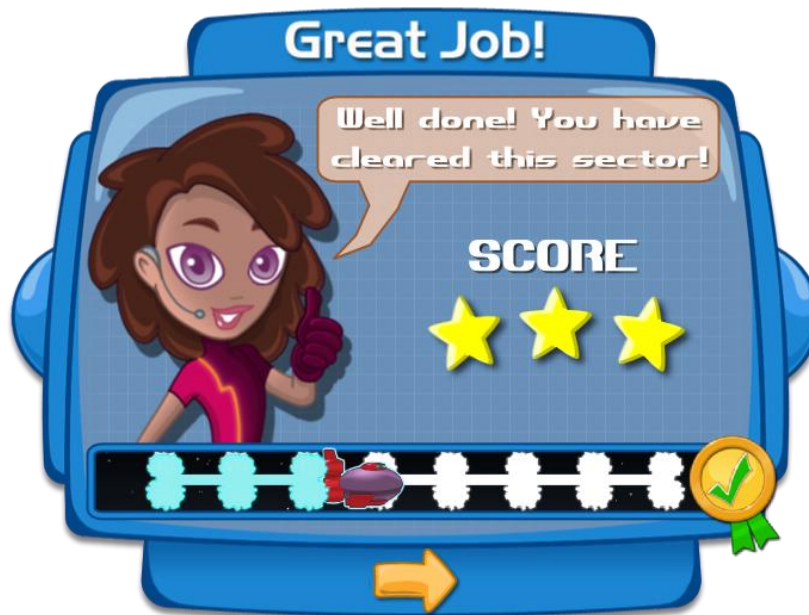
- Change name of the public game to *SpaceForce* in order to distinguish it from the research version (*RoboBall*)
- Adding more in-game audio

- Add story narrative to in-game movies
- Added a feature to make the game movies skip-able
- Remove SELs from the level flow (drive this via a server variable?)
- Remove end-of-level references to chest collection
- *Hide Collections button and screen
- * Hide Achievements button and screen
- * Unlock all levels in Mission Select menu
- Simplify "3 strikes you're out" level flow
- Add "star rating" performance metric to end-of-level menu
- * Make all adaptive levels mandatory
- If *, allow retries on assessment levels; otherwise, add "Captain Dialog" to levels at start of unit and on assessment levels
- Add "progress indicator" to end level dialog
- Add "performance summary" at "end of unit"
- Add tutorial for first assessment level
- Unlock the first level in each of unit in the "Review" menu.
- Added in-game text to further clarify the narrative.

"LEVEL END" SUCCESS DIALOG CHANGES

We replaced the current "level end dialog" with a version that rates the player's performance on the Level and shows their progress within the Unit.

The "Level Success" version of the dialog looks like this:



When players complete a level, the game awards them a score:

3 stars: completed on first try

2 stars: completed on second try

1 star: completed on third try



When players fail a level, they receive a "strike." After three strikes, the player must start the unit over. Strikes accumulate from level to level.

6.12. CAPTAIN DIALOG

At the start of each Level, we now present a "Captain Dialog" that explains the upcoming challenge and shows the player's progress through the unit:

The dialog will look something like this:



The Captain Dialog appears at the start of every level. It shows the player's progress through the unit, explains the physics, and offers game play hints.

In the first level of each unit, the Captain Dialog displays the following text:

- Intro to Unit 1: "Use the gloves to push your RoboBall into the treasures chests."
- Intro to Unit 2: "The glove with the big arrow pushes hard. The other glove pushes softly."
- Intro to Unit 3: "The heavier an object is, the harder it is to move it."
- Intro to Chapter 4: "What will happen when you give an object two pushes at once?"
- Intro to Chapter 5: "What happens when you push an object that is already moving?"
- Intro to Chapter 6: "How can you stop an object, or make it go backwards?"
- Intro to Chapter 7: "Only a few chests left, but these are the hardest puzzles."

6.13. UNIT SUMMARY

At the end of each unit, the game will provide a "unit summary" level which features a "stats" dialog:



The dialog will reports the number of levels cleared and stars earned while playing the unit.

6.14. REVISED LEVEL FLOW

The BrainPOP team has indicated that the existing level flow confuses players in two ways:

- 1) The order of presentation of concepts seems muddled, and
- 2) It's unclear why the game allows retries on some levels but not others.

To combat these problems, we have revised the level flow as follows:

- 1) Present assessment levels only once, at the end of the unit to which they belong.
- 2) Allow retries on all levels, including assessment levels.
- 3) Make level progression consistent by requiring players to complete all adaptive levels*.

**Ideally, we still support adaptive content by placing "warp gates" on the progress track, then allowing players to "warp past" adaptive levels whose content they had already mastered. Unfortunately, this system complicates the progress map and performance screens, so we probably don't have the time or budget to implement it.*

6.15. DISPLAYING REMAINING ATTEMPTS

We will replace the existing "crew" meter in the upper right corner of the level display with a "strike count," that shows 0, 1, or 2 strikes, depending on the number the player has earned.

6.16. NEW LEARNING CATEGORIES

In the absence of persistent user data (which we cannot collect), we track learning targets per unit. We define the new "per unit" targets in terms of the learning targets used in the original version of the game as follows:

- Unit 1: Which direction to push?
- Unit 2: How hard to push?
- Unit 3: Heavy objects vs. light ones
- Unit 4: Two pushes at once
- Unit 5: Adding pushes
- Unit 6: Subtracting pushes
- Unit 7: Adding and subtracting

6.17. INITIAL LEARNING TARGETS

We present the learning targets in plain language, shown in bold next to the definitions we use in the design Assessment and Adaptivity Design document.

- **M2-1:** The larger the push or pull (impulse) acting on a body, the larger the change in the object's momentum

Target F1: Students can demonstrate that a force is a push or pull that can change an object's position and put it into motion. **BACKGROUND:** The position and motion of an object can be changed by pushing or pulling. An object at rest will stay at rest unless a force is applied.

- **F1-1:** A stationary mass, when pushed or pulled, moves in the direction of the push or pull
- **F1-2: CLARIFICATION** – in the absence of external forces like gravity, pushes and pulls behave identically in all directions

Target F2: Students will demonstrate understanding that the more massive an object, the more force is needed to set the object into motion in the direction of the force. Mass is the amount of matter in an object. Mass is not the same as size. Force is a push or pull

- **F2-1:** Given the same impulse, the heavier of two masses will experience a smaller change in motion
- **F2-2:** Given two objects of equal mass, that which experiences the larger impulse will experience a greater change in motion (this is a restatement of M2-1, so we combine them – averaged)

Target F3: Students are able to explain that forces are composed of magnitude and direction.

BACKGROUND: Magnitude of force is its size and strength. Force always has a direction.

- **F3-1 (goal 17):** Given two impulses at right angles to one another, students can predict the resultant direction
- **F3-2 (goal 18):** Given two opposing impulses acting on a single mass, students correctly predict whether or not impulses cancel

6.18. NEW LEARNING CATEGORIES EXPRESSED IN TERMS OF OLD LEARNING TARGETS:

- Unit 1: Which direction to push? (F1-1, F1-2)
- Unit 2: How hard to push? (All from unit 1 and M2-1)
- Unit 3: Heavy objects vs. light ones (all from unit 2 and F2-1)
- Unit 4: Two pushes at once (all from unit 3 and F3-1)
- Unit 5: Adding pushes (all from unit 3 and F3-1)

Unit 6: Subtracting pushes (all from unit 3 and F3-2)

Unit 7: Adding and subtracting (all learning targets)

6.19. REVIEW MENU CATEGORIES

We allow players to jump to the start of any unit via the "Review" menu. To facilitate this, we will unlock the first level of each unit in the menu and disable dynamic unlocking. This will allow the players to choose the first level of any unit at any time in the game. Jumping to a new unit resets the player's accumulated "stars and strikes."

We've added an auto-tutorial to the first assessment level so students understand the new placement mechanic (i.e., placing the chest instead of the gloves or balls).

6.20. UIX IMPROVEMENTS

We've implemented the following UIX features:

- Improve the visibility of the "skip movie" arrow
- Replace the "next level" button with the "skip movie" arrow

6.21. GAME CONCLUSION

At the conclusion of each Mission (unit) the player will receive a Mission Report. This report is printable in the event a teacher would like proof of Mission completion. The Mission Report indicates the level pass/fails and the time played. The player is congratulated and presented with a screen of their achievements. These achievements, as well as all of the game metrics are recorded by the Web Server.



Figure 3.0 – Student Friendly Mission Report

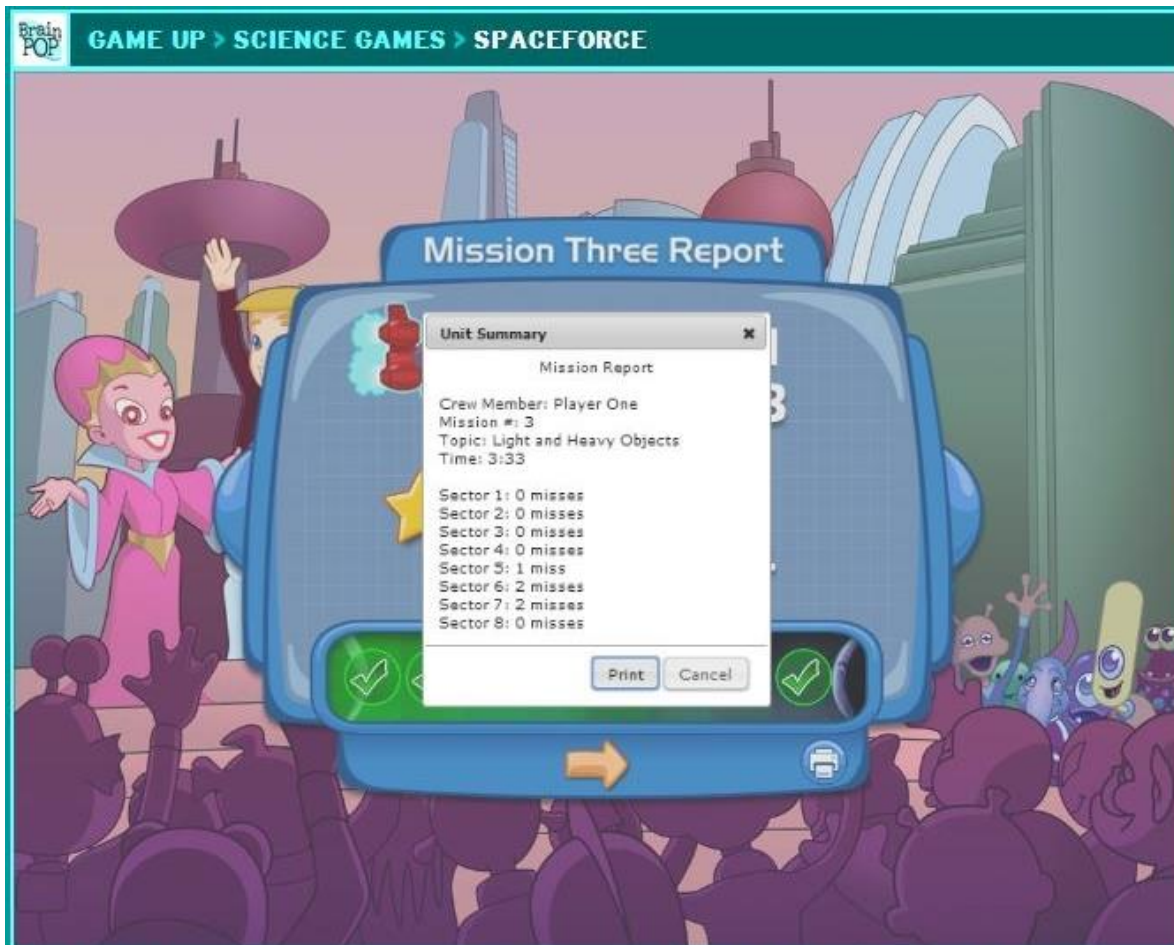


Figure 3.1 – In-Game Printer dialog for the Mission Report

4/23/2014 GAMEUP | SpaceForce

Mission Report

Crew Member: Player One

Mission #: 3

Topic: Light and Heavy Objects

Time: 3:33

Sector 1: 0 misses

Sector 2: 0 misses

Sector 3: 0 misses

Sector 4: 0 misses

Sector 5: 1 miss

Sector 6: 2 misses

Sector 7: 2 misses

Sector 8: 0 misses

<http://www.brainpop.com/games/spaceforce/> 1/1

Figure 3.2 – Printed version of the Mission Report for teacher verification

7. A MULTI-FACETED GAME ENVIRONMENT

We have ultimately developed two versions of our game available for further learning by the community; *RoboBall* and *SpaceForce*.

7.1.1. THE ROBObALL RESEARCH VERSION

RoboBall is our research version used mainly for efficacy and assessment testing. It has features that support the collection of finer user metrics. The *OurSpace* game portal was designed

specifically with data collection and research in mind. It's a one-stop-shop for researchers, game designers and students. By using authorized credentials a user can access game data, redesign levels and play the game. This is possible because our game is built in html5, a powerful web-based technology.

When CRESST uses our *RoboBall* game for testing they know the demographics of their student population. We are able to pre-populate our database with logins for students in Kindergarten through Fifth grade. This allows CRESST to analyse how well certain age groups perform. In addition to the pre-populated logins the research version includes adaptive learning predicated on integrated pre and post-tests. When a student reaches a pre-test assessment we evaluate how well they do on the level and record their performance. Then later on in the unit a post-test assessment is presented to the user.

We typically present this to the user 7-10 levels after the pre-test to record their performance once again. The number of levels between each assessment is determined by how well the student performs immediately following the pre-test at the beginning of a unit. Our adaptive learning algorithm calculates how well the student is doing on specific learning targets that the levels are based on.

If the student meets the passing percentage they move ahead to more difficult levels. If the student fails to meet the minimum requirement they will receive remedial levels to reinforce the learning targets. These remedial levels restate the physics problem in a different way to give the student a new perspective. *RoboBall*, the research version of our game that CRESST uses for testing can be played here: http://engage.intific.com/engage_portal/public/.

7.1.2. THE BRAINPOP SPACEFORCE VERSION

The second version of our game, *SpaceForce* is our public-facing game currently hosted on BrainPOP. Per their recommendations, we renamed *RoboBall* to *SpaceForce* to distinguish it from the research version, *RoboBall*.

In late 2013 we reached out to BrainPOP to discuss a possible partnership. We set up a video conference where we discussed our *RoboBall* game with them. They wanted to know everything about the game, its learning strategies and goals, as well how to play. We gave them a demonstration to walk them through all the game has to offer. We also provided technical and creative information as needed.

BrainPOP asked that we give them access to the game so they could review it with their game development team. We gave them access to our game and waited to hear back. After reviewing the game with their team they informed us that they were impressed with the game and felt that it's learning goals match-up nicely with their audience. They gave us feedback on some of the areas that they felt needed adjustment based on what their audience needs and what their technology supports. Within a few months we revised the game to meet their requirements and got it running on their site. During this process we've built a strong relationship with their team. They asked us to join them at 2 education conferences in Austin, Texas to present our game at their booth. We accepted their invitation and presented at the Texas Computer Education Association conference and at the South by South West Education conference.

SpaceForce had several different features added to it based upon recommendations from the BrainPOP team. These were mainly due to technical limitations on BrainPOP that we had to adjust for. BrainPOP Jr. doesn't support individual logins. This kept us from leveraging persistent user data to drive the progression based game features like; individualized data capture, adaptive learning, saved games, unlocked levels, achievements and awards. Because of this we created new interfaces to communicate mission (unit) selection, level progression and pass/fail states. *SpaceForce* is available on BrainPOP here: <http://www.brainpop.com/games/spaceforce/>.

7.1.3. SERVER AND GAME EDITOR INFORMATION

The server for *OurSpace* is based on a number of commercial products (Linux, Apache, MySQL, PHP: LAMP Stack) and is targeted to run in any HTML Browser that supports Flash. The prototype application developed in Phase 1 was created in Flash. In order to provide the desirable level of cross platform compatibility and the ability for multiple points of game edit/creation (Educator, Developer, and Administrator), we developed a game engine in HTML 5. This is the platform used to develop all milestones and the final build in Phase 2.

8. RECOMMENDATIONS

Through this deliberate fusion of the most rewarding aspects of game creation and play, with educational objectives and instructor lead learning, we have developed a method and tool base which can be expanded to address multiple types and levels of interactive learning.

The Prototype Game is being tested by CRESST/UCLA, including the statistical information being collected. We anticipate their report by the end of the summer in order to incorporate the recommended changes into the Test-Ready game.

We have finished the Phase II work, expanding the capabilities with the goal of interim deliverables met and a test-ready game software after 6 months and Final Game software 23 months after award of Phase II. The incremental funding allocated in the initial transaction was sufficient to continue work through portions of October. Additional resources during the early months of Phase 2 let us accomplish the engineering, game design and art requirements needed to meet the test-ready game deliverable. Intific recommends consideration of additional funding, to ensure continuity of effort.

8.1.1. EXTENDING OURSPACE IN THE CLASSROOM

The concepts covered in *RoboBall* can be coupled with both science and mathematics curriculum. *RoboBall* maps onto the Next Generation Science Standards (NGSS) (NSF, 2013). The game mechanics in *RoboBall* are consistent with the *Performance Expectations* contained in Table 4, covers the NGSS *Disciplinary Core Ideas* contained in Table 5, and requires the use of the *Science and Engineering* practices contained in Table 6.

Table 4

NGSS Performance Expectations Related to *RoboBall*

Performance Expectations

K-PS2-1	Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object.
K-PS2-2	Analyze data to determine if a design solution works as intended to change the speed or direction of an object with a push or a pull.
3-PS2-1	Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.
MS-PS2-2	Plan and conduct an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

Table 5NGSS Disciplinary Core Ideas covered in *RoboBall*

Disciplinary Core Ideas		Related Performance Expectations
Forces and Motion	Pushes and pulls can have different strengths and directions.	K-PS2-1 K-PS2-2
	Pushing and pulling on an object can change the speed or direction of its motion and can start or stop it.	K-PS2-1 K-PS2-2
	Each force acts on one particular object and has both strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on the object. Forces that do not sum to zero can cause changes in the object's speed or direction of motion.	3-PS2-1
	The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change.	MS-PS2-2
Energy	The faster a given object is moving, the more energy it possesses	K-PS2-1 K-PS2-2
Defining Engineering Problems	A situation that people want to change or create can be approached as a problem to be solved through engineering. Such problems may have many acceptable solutions	K-PS2-1 K-PS2-2

Table 6

NGSS Performance Expectations Related to *RoboBall***Related Science and Engineering Practices****Asking Questions and Defining Problems**

Asking questions and defining problems in grades 3-5 builds on grades K-2 experiences and progresses to specifying qualitative relationships/

- Ask questions that can be investigated based on patterns such as cause and effect relationships.
- Define a simple problem that can be solved through the development of a new or improved object or tool.

Planning and Carrying out Investigations

Kindergarten. Planning and carrying out investigations to answer questions or test solutions to problems in K-2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions.

- With guidance, plan and conduct an investigation in collaboration with peers.

3rd grade. Planning and carrying out investigations to answer questions or test solutions to problems in 3-5 builds on K-2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.

- Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials are considered.
- Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution.

Analyzing and Interpreting Data

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- Analyze data from tests of an object or tool to determine if it works as intended.

In the domain of mathematics, *RoboBall* is aligned with three *Common Core State Standards*:

1. Reason abstractly and quantitatively.
2. Describe measurable attributes of objects, such as length or weight. Describe several measurable attributes of a single object.
3. Directly compare two objects with a measurable attribute in common, to see which object has “more of” / “less of” the attribute, and describe the differences.

Related Formative Assessment Probes (Keely & Harrington, 2010)

- Is it possible to make the ball roll at a constant speed (i.e., when the ball is neither slowing down nor speeding up)?
- What is a force?
- Present students with common misconceptions about force and motion and ask them to explain their thinking about those ideas.
- How would someone walk to school if there were no friction in the world?

Related “Real-World” Examples

Common hands-on exercises that can be used to accompany *RoboBall* gameplay include the following:

- Measure the distance and/or the time it takes for various objects (cars, balls, boxes, blocks) to travel along different surfaces.
- Have students walk side by side at different speeds while dropping a rock on the ground at steady intervals. Examine the differences in the ‘rock trails’ left by each student.
- Have students generate examples of difference things that exert a force or are acted upon by forces. Use those examples to go on a “forces scavenger hunt”.
- Have young children push or pull on objects using their own muscles.
- Play *RoboBall* charades by giving students a scenario depicted in one of the levels of *RoboBall* and having kids act it out.

9. OURSPACE TEST RESULTS

OurSpace focus tests were conducted by CRESST/UCLA on the following dates:

- **Summer 2012** (Flash Build)
 - Playtested with 80 students
 - Pilot effectiveness study with 62 students
- **February-March 2013** (Beta)
 - Pilot effectiveness study with 80 students
- **December 2013** (Beta)
 - Usability testing with 41 students
- **April 2014** (Final)
 - Usability testing 20 students (Most finished the game)
 - Grades and number of students: 3rd (3), 4th (9), 5th (12).



Extensive testing during the summer is planned, and Intific is standing by to respond to the results obtained.

CONTRACT COSTS

REPORT DATE: 05/30/14	INTIFIC, Inc.		
PERIOD ENDING: 05/31/14			
	PROJECT MGR:	Kristy Tipton	
JOB SUMMARY REPORT			
CLIENT: ONR	EST TOT VAL:	3,936,951.00	
PRIME CONTRACT ID:			
N00014-11-C-0593	AS OF 05/31/14	FUNDED VALUE:	3,936,951.00
CONTRACT TYPE	CPFF		
TOTAL CONTRACT INCURRED COSTS			
Direct Labor		1,278,475.00	
TOTAL LABOR COST ²		1,278,475.00	
Subcontractor		454,454.00	
Direct Travel		30,224.00	
Other ODC's		18,141.00	
TOTAL OTHER DIR.COST		502,819.00	
TOTAL INDIRECT EXP.		1,897,626.00	
TOTAL CONTRACT COSTS		3,678,919.00	
FEE COMPUTED 7.00		257,524.00	
CONTRACT REVENUE		3,936,443.00	

² Note: this figure is based on actuals through 5/16/2014 and projections through 5/30/2014

9.1. HARDWARE PURCHASES

Contract Report: Hardware Purchases			
Contract Number:	N00014-11-C-0593		
Description:	ENGAGE PROGRAM		
Internal Contact:	Kristy Tipton		
Licenses:	1		
Begin Date:	8/10/2011		
End Date:	5/31/2014		
Asset Tag:	Asset Type:	Description:	Site:
dENGAGE-10001	Mac Mini desktop	Mac Mini desktop, Mac Mini desktop	Austin - Jollyville
dENGAGE-10002	Samsung 840 SSD 120GB	Samsung 840 SSD 120GB, Samsung 840 series SSD Hard Drive 120GB	Austin - Jollyville
DIR-10113	Samsung 840 SSD 120GB	Samsung 840 SSD 120GB, Samsung 840 series SSD Hard Drive 120GB	Austin - Jollyville
DIR-10113	Samsung 840 SSD 120GB	Samsung 840 SSD 120GB, Samsung 840 series SSD Hard Drive 120GB	Austin - Jollyville
INT-11193	iPad 64GB Wifi	iPad 64GB Wifi, Refurbished Gen I iPad, 64GB WiFi	Austin - Jollyville