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Using Gamification to Persuade More Women and Minorities into STEM

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Abstract

This report looks at several educational design techniques used by Intergalactic Education LLC over the last three years to motivate more students into pursuing a STEM career, more specifically: underrepresented demographics, ages 11-14. The software platform tested during this study utilizes a compelling storyline, machine learning, and friendly competition to promote science, technology, engineering, and math within secondary school systems.

This report contains lessons learned from the pilot programs conducted by Intergalactic Education within the Charles County Maryland School District. During this period, three classes of 8th-grade honors algebra students were allowed access to a simulation game called Space World™. One of the teachers involved in the program was chosen by the Space Foundation to become a part of their selective Teacher Liaison Program cohort.

This analysis also identified a number of shortcomings in existing education technology solutions. The research indicates that most digital instructional products do not have the high-fidelity graphics and animations that millennials have come to expect from applications they download on their handheld computers. Additionally, teachers and school administrators are not effectively leveraging big data collection that should be integrated into existing curriculum.

Keywords: Education, STEM, Space World, gamification, 21st century, cultural development

Acronyms/Abbreviations
Artificial Intelligence (AI)
Amazon Web Services (AWS)
Next Generation Science Standards (NGSS)
Optical Character Recognition (OCR)
Science, Technology, Engineering, and Math (STEM)
Small Business Innovation Research (SBIR)

1. Introduction

Intergalactic Education LLC is a software company that works directly with schools and afterschool programs to teach young teenagers (junior high school students) about the importance of Science, Technology, Engineering and Math (STEM). We have a focus on inspiring more young girls and minorities into following engineering career paths. Our team has developed an educational computer game called Space World™ that motivates students through the use of incentives and competition. Students compete across schools for high scores while new game content unlocks upon the completion of math and science modules throughout the storyline.

The software has been in use in schools since the Fall of 2016, when it was piloted at Milton M. Somers Middle School in La Plata, Maryland. During the second evaluation of the software, Charles County Public Schools Superintendent, Dr. Kimberly Hill, stopped in to watch students launch and land rockets while solving algebra problems in *Rocket Math*.

Additionally, Space World™ has been used in a number of after-school environments (Montgomery County *Excel Beyond the Bell*), including one elementary school (Oak View Elementary), in a high school STEM class (Quince Orchard High School), at multiple STEM conferences, at a space-themed summer camp, and on display for politicians during the Entertainment Software Association's Games for Impact event on Capitol Hill.

Fig. 1. Justin Park with Congressman Bill Foster (D-IL)

1.1 Original Goals

The fundamental idea behind the software is to use gamification to inspire and teach students in a creative way that is more engaging than learning out of a textbook. During our original customer discovery and market research, however, we also identified a number of deficiencies and ways in which other digital education programs fall short.

The first is that there is not enough automation in the way student work is assessed. Teachers constantly complain about not having enough time in their busy schedules because they spend on average six-hundred hours per year grading homework assignments. This trivial task is nothing more than useless data entry that should be conducted by an artificial intelligence. Intergalactic Education has developed a basic AI for grading and analysing the mathematics portion of Space World™.

Additionally, children have essentially an infinite number of other applications and programs competing for their attention, so it is important to ensure that the software is fun and motivational. Most educational products are not. They do not have the graphics and animation quality that the younger generation has come to expect. Existing educational applications on the market also do not captivate students because they do not effectively leverage new technologies like gamification and mobile computing. We have done our best to create an amazing looking computer game with a compelling story about humanity's future in space, and it runs on both *Android* and *iOS* operating systems.

Last but not least, administrators are not utilizing valuable statistical information that is a result of recent advancements in big data collection. Historically it has been difficult to accurately assess teaching performance because everything was analogue (i.e. non-digital). This leads to an even bigger problem because teacher performance is tied to compensation and pay raises at the end of the year. A combination of poorly designed software and logistical constraints has so far prevented a scholastic renaissance from taking place. A paramount shift in the way students learn and the way teachers are assessed is going to take place once we finish building out our AI and properly disseminating the platform.

1.2 Refocus on under-represented demographics

At some point in early-to-middle of 2018, future Space World™ storyline development became more focused on getting more young girls and minorities interested in following STEM careers. Intergalactic Education leadership recognized the importance of closing the huge gap in the number of women and men in the aerospace industry as shown in Figure 2.

Additionally, the company began working more directly with disadvantaged and Title I students, most of whom are black. One solution for engaging these students was to swap out the previous main character, astronaut Joe, for a female African American astronaut character. Some literature suggests that individuals are able to relate better to people who look physically like themselves or have some form of cultural connection.

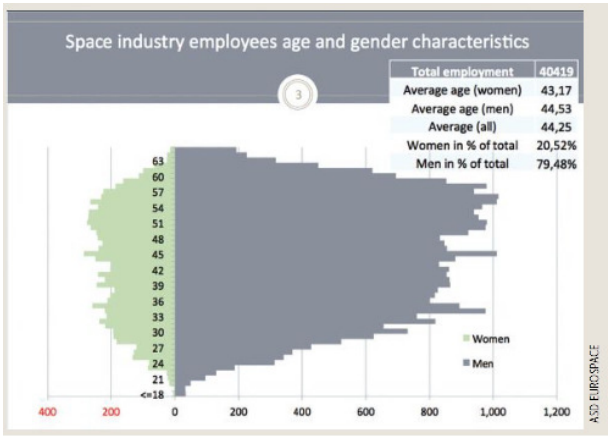

Fig. 2. ASD Eurospace study on gender/age distribution

2. Materials and methods

Reproducing the exact same results as were collected during our pilot programs is nearly impossible as the software is constantly being updated with new materials. Just this summer, Intergalactic Education added six more algebra modules to the *Rocket Math* minigame. The software, which is still considered to be in beta version, will likely continue to evolve indefinitely as we collect more data.

2.1 Software architecture and data collection

The core of the product is built around a *Microsoft SQL Server* database and .NET data collection web service that run on Amazon Web Services (AWS). The Space World™ application itself was engineered using Unity3d, a popular cross-platform design tool that makes it easier to import and manipulate model, graphics, sounds effects, animations, videos, and programming scripts (C#). *Microsoft Team Foundation Services* acts as our versioning control, task management, and team collaboration system, all of which integrate together beautifully with Unity3d.

Unity3d was chosen also because it has a large engineering community and a framework that supports AR/VR development. The platform itself has its own physics engine, which was leveraged when we designed the rocket landing and Spaceball minigames.

One thing that should be noted about our data collection process is that no personally identifiable information is stored on our servers. We are only able to identify students by their usernames, which are chosen the first time a student logs in. The username to student name index is kept offline by the teacher. Additionally, a homework grading tool was designed to allow

teachers to assign students points for showing arithmetic work. This is made possible because screen capturing capabilities are built into the data collection engine on the backend of the software. Images can be sorted by student or by question to enhance the grading speed of the educator.

2.2 Administering Space World

The first teacher to utilize the Space World™ software was Mr. David Wood of Milton M. Somers Middle School. On three separate occasions, his three classes of 8th grade honors algebra students used the software for a period of 80 minutes. It should be noted that prior to the students using the software, Mr. Wood energized them by explaining how they are the first to try the application. As will be discussed in the results section, this important element, teacher enthusiasm, leads to better scores.

Fig. 3. Justin Park with student at Milton M. Somers Middle School

2.3 Data analysis

After each pilot, results of the students were provided to the teacher. A small sample of the raw *Rocket Math* data collected can be found in Appendix A. Information from our database can be grouped in a number of different ways to identify which students are having the most trouble and in which areas the most students are having problems.

3. Theory and calculation

The theory that games can be used as an abstraction and simplification of real-world scenarios is discussed at great length in Karl Kapp's publication on Game-based Methods and Strategies for Training and Education. [1] During his research, he found that gamification, multi-variable strategy games in particular, are an effective method for teaching the problem-solving process.

Originally, to limit the scope of the project, we decided to focus our development energies on only targeting American students. This decision was made due in part to the location of Intergalactic Education being in the United States, the persuasion of early stakeholders and advisors to the company, and the lack of resources for proper localization in alternative languages. One major problem identified by early stakeholders is that public elementary schools within the United States do not lead in math and science. They are actually not doing very well at all. According to the Programme for International Student Assessment, in 2015 the United States ranked 40th in math and 25th in science when compared to other elementary education programs globally. [2]

As a nation, the United States has over 37,000 secondary schools that stand to benefit from better educational software products. There is the potential of saving teachers millions of hours correcting homework assignments every year. Additionally, there is the opportunity to motivate this generation of students – roughly 74 million children under the age of eighteen – into becoming the knowledge leaders of tomorrow. Without the newest tools and techniques, children run the risk of falling behind in an ever-increasingly competitive world. Current STEM software does not inspire like it should. Adolescent children need to have a compelling reason to learn. Disadvantaged minorities in particular need to understand that there is a bright future ahead of them if they do their work and pursue a career in one of the STEM fields.

Our end-user research indicated to us that most digital instructional products do not have the high-fidelity graphics and animations that millennials have come to expect from applications they download on their handheld computers. It is for this reason that during the design phase of Space World™, great emphasis was placed on having amazing graphics to set our product apart from other existing educational software applications.

Fig. 4. *Rocket Math* minigame screenshot

4. Results

One mechanism that was added early to our machine learning algorithm is to automatically serve up easier problems to students that answer several questions in a row incorrectly. This process is used because we do not want users to become discouraged. While most of our results were positive, it was not possible to get every student to enjoy their math learning experience. Typically, the students who were better at the subject matter were the ones who would return and use the software outside of scheduled Space World™ time.

One positive method that worked universally across the students who piloted the software was the promotion of friendly competition between classes and schools. Teachers and onsite educators can serve as major motivators to promote competitive learning within their local geography. They serve more like STEM coaches in the middle of a big game when students can see other high scores in real-time. We hope to begin having competitions in which schools compete against one another at the same time throughout the day.

Fig. 5. Real-time results from Milton M. Somers pilot

One bit of important feedback that we received from a number of female students is that we need more dogs and puppies in the software to appeal to the younger girls. While the software is not violent in any way, the storyline could benefit from more lovable animal characters.

5. Discussion

Gamification is an important construct for educational software to use because it allows students to take on different roles and see complex problems from multiple perspectives. [3] Space World™ intends to shows students what the space industry will look like at a micro and macroeconomic level. Most of the content designed to teach students about the orders of magnitude involved in space economics have not been integrated into the software yet. This is a result of forcing teachers into educating students to pass a standardized test at the end of the year when student progress should be constantly monitored and tests eliminated. Too much focus is being placed on Next Generation Science Standards (NGSS) and Common Core tests. There is not enough room for creativity or systems thinking.

Gamification leads to better systems thinking. [4] According to the literature, this has been proven many times. Models and simulated environments can act as powerful tools to teach young adults about the way the world works.

Additionally, teachers and school administrators are not effectively leveraging big data collection and machine learning that should be integrated into existing curriculum. There is no reason the homework should not grade itself. In order to fully automate this process, Optical Character Recognition (OCR) needs to be implemented. OCR is not currently built into Space World because it is a hard problem to solve. There exist third-party companies that specialize in OCR but those solutions are expensive. Instead, we have developed a proprietary algorithm to pseudo-randomly generate an infinite number of questions. Our machine learning technology uses this data to improve test scores through repetition.

6. Conclusions

Space World™ has proven to be an effective educational tool for motivating students, tracking their progress throughout their experience, and providing educators with data that can be used to show how quickly they are advancing.

Intergalactic Education needs to continue to improve the algorithms behind all of our amazing graphics. We are in the process of submitting a Small Business Innovation Research (SBIR) grant to the National Science Foundation to continue improving our AI agent. There are additional Department of Education SBIR solicitations Intergalactic Education is also planning on responding to in early 2020. After the software has been better proven, the goal is to reach millions of students, not just in the United States, but all around the world. Everyone should understand the importance of STEM and the role that the space economy has to play in the future.

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Appendix A (Raw Data Sample – Results on 12/18/2017)

EquationId	PlayerId	QuestionType	Question	Answer	Correct	TimeStamp
00cc5611-d547-453a-bfd4-0e0fb66f8be9	orangeJUice	DisplayQuestion	19x - 10 = -200	-23	0	2017-12-18 08:05:05.000
14ceea53-0732-4132-b823-8aac5e5a94eb	Theultimateclogger	DisplayGraph	y = -3x-4	y = -3x-4	1	2017-12-18 08:05:08.000
dbb5078f-6725-4220-a5a2-3a7eef55874c	orangeJUice	DisplayQuestion	19x - 10 = -200	-11	0	2017-12-18 08:05:08.000
38d3496f-504c-4929-9575-09951f186816	Bobbythegreat	DisplayGraph	y = 4x-2	y = 4x-2	1	2017-12-18 08:05:10.000
b3ae2b0d-dc9c-4154-88a0-8ca24b117e8a	ninckiminajj	DisplayQuestion	-9x - 7 = -16	1	1	2017-12-18 08:05:10.000
a0d91f00-3802-464f-a3af-0ffcec74a7c2	kayleigh	DisplayQuestion	x + 8 = 7	-1	1	2017-12-18 08:05:13.000
2513e6fc-ea07-45fc-9dba-caf09d8b1c66	chicken	DisplayGraph	y = 4x+2	y = 4x+2	1	2017-12-18 08:05:16.000
d90836a7-8cff-447a-afd3-6deb742f12f5	Pudding	DisplayGraph	y = -2x+3	y = -x+3	0	2017-12-18 08:05:16.000
a91aa889-1eef-487d-af3c-995d49b95736	Pudding	DisplayGraph	y = -2x+3	y = 3x+3	0	2017-12-18 08:05:18.000
04737366-6c43-43b9-9166-ab46074faf88	Bobbythegreat	DisplayGraph	y = 3x-4	y = 3x-4	1	2017-12-18 08:05:19.000
4e42e280-e5f0-40b7-b28b-c4b5a0e9935d	Theultimateclogger	DisplayGraph	y = 3x-1	y = 3x-1	1	2017-12-18 08:05:22.000
52d8eb4a-087c-4414-9fd1-477e42dba730	chicken	DisplayGraph	y = -3x+1	y = -3x+1	1	2017-12-18 08:05:23.000
2cb2ad16-9fd9-4529-a370-ac4078fa136a	Alena	DisplayGraph	y = -4x+1	y = -4x+1	1	2017-12-18 08:05:25.000
c7fcc071-b229-4f15-99b8-923ea3210227	ninckiminajj	DisplayGraph	y = -x+4	y = -2x+4	0	2017-12-18 08:05:27.000
e1151c85-101e-4cbe-aeb8-cece8bda4eeb	Theultimateclogger	DisplayGraph	y = 4x-4	y = x-5	0	2017-12-18 08:05:28.000
9faf15ae-0870-4c50-89bc-842ab96c2831	Theultimateclogger	DisplayGraph	y = 4x-4	y = 2x-5	0	2017-12-18 08:05:29.000
b32a4f7e-3bfb-4d56-852c-a97c4ef8a00b	24601	DisplayQuestion	-12x - 6 = -126	13	0	2017-12-18 08:05:30.000
7e214031-7ca1-4275-9cf5-1c6e6e11b20f	ninckiminajj	DisplayGraph	y = -x+4	y = -x+4	1	2017-12-18 08:05:30.000
737e9118-cc8e-4bcc-8bd9-3f3262539867	FabioEnchillada	DisplayQuestion	13x - 7 = -111	-22	0	2017-12-18 08:05:32.000
09a28c74-fc0e-4813-b4df-1d21dd77bba8	Alena	DisplayGraph	y = x-5	y = x-5	1	2017-12-18 08:05:32.000
e71bce2a-c2e2-4ec2-b1ff-22883c12d67d	24601	DisplayQuestion	-12x - 6 = -126	8	0	2017-12-18 08:05:32.000
9c859c12-738a-4a8a-a5c2-c5ff04e9f17c	FabioEnchillada	DisplayQuestion	13x - 7 = -111	-11	0	2017-12-18 08:05:34.000
cf2feed9-4e29-4452-af54-8d9bfb041792	ninckiminajj	DisplayGraph	y = -5x-5	y = -5x-5	1	2017-12-18 08:05:37.000
2c205690-4022-4122-acb6-744000ac2255	kayleigh	DisplayQuestion	-10x - 7 = -7	0	1	2017-12-18 08:05:41.000
4efee006-0904-4921-beff-c66a7a520d75	ninckiminajj	DisplayGraph	y = 4x+3	y = 4x+3	1	2017-12-18 08:05:43.000

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