The Middle School STEM Achievement Gap, Technology-Based UDL – and Alien Rescue

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"I saw early on that technology could be very beneficial for my students," declares Dr. Marino, "especially those with learning disabilities. It was the key to helping me when I was in the classroom teaching science. I returned to school to earn my Ph.D. in special education so that I could focus on the kids who struggled the most.

"The difficulties for these kids begin when they arrive in middle school. That’s where the achievement gap widens. When they reach fifth and sixth grade they undergo a transition. In grades K – 4 they learn to read. During middle school they read to learn. Then they encounter middle school science and math. That’s where the achievement gap becomes even more evident and pronounced."

What Dr. Marino could not imagine when he was a young special education teacher was that one of the keys to possibly narrowing the STEM achievement gap for his middle schoolers with disabilities would appear in the form of an online game that encompassed the principles and benefits of a technology-enhanced Universal Design for Learning (UDL) format.

The Benefits of UDL, Principle by Principle

In Dr. Marino’s opinion, the three principles of UDL, especially when bolstered by technology, can be instrumental in helping to close middle schoolers’ STEM achievement gap. He addresses UDL’s utility, principle by principle:

**Principle One:** Multiple means of representation to give learners various ways of acquiring
"The first principle of UDL," according to Dr. Marino, "states that specific information can be presented using multiple flexible methods to support students' recognition networks. If we were to apply that to an example in a STEM class, teachers could use technology to support understanding of new material by presenting information using alternate formats, for instance."

He cites an in-classroom bridge construction experiment as an example. "This is a typical middle school science lab exercise in which students use tongue depressors as building materials. The objective is to design a bridge that can carry a maximum amount of weight. The students build the bridge using glue and tongue depressors. Students continually add weight to learn how much weight the bridge can bear. The team that builds the most structurally sound bridge wins the competition. Data is recorded as the competition proceeds.

"If that data is in numerical form, students who are proficient in math will easily interpret the data. However, technology enables students to employ a meter that's connected to the bridge and that takes data from the amount of weight applied. The data can say, for example, 'When this weight was applied, the bridge dropped .2 centimeters.' The technology enables students to collect more specific information which can then be transformed for presentation in table and graph form. We can replicate that and conduct more complex statistical analysis to show a regression line, for instance, to students with disabilities.

"If a teacher talks about regression with students with disabilities those students may be lost right there. But if a teacher can put up a line that shows, for instance, that added weight exerted at a certain point on the bridge produces a specific consequence and make a comparison with other designs, the students with disabilities have a powerful visual way to get that information."

**Principle Two:** Multiple means of expression to provide learners alternatives for demonstrating what they know.

Principle Two, Dr. Marino explains, “provides for multiple, flexible methods of expression to support strategic networks. The strategic networks are how students think about thinking.
Using technology, this can be achieved by imbedding an expert modeling tool within the technology interface. For example, a child is completing an online investigation of a scientific phenomenon – and the child is struggling. If the teacher has a tool that allows an expert to say to the child, ‘Here’s the information you have now; if I were you this is what I’d try next.’ The expert would model his/her suggestion on-screen for the student. This is a powerful scaffold that’s built into the technology interface that improves accessibility.

“This tool is not limited to use by students with disabilities and could be utilized with English Language Learners, for example. It can also be made available on-demand to kids who struggle with reading but are not necessarily identified as having a [learning] disability. A majority of kids with disabilities, if they’re struggling, won’t ask the teacher for help. If there’s a technology-based tool that incorporates expert modeling, the student can click on it and obtain as-needed feedback in a lab setting.”

Dr. Marino offers another example of how technology can scaffold students’ learning. “If a science teacher is conducting an investigation of the individual elements, or of combinations of elements, technology can provide a built-in periodic table. I spent a lot of time when I was an undergrad trying to memorize the periodic table. It wasn’t until I started working with it and teaching it that I learned it cold. For a student with a learning disability memorization of all of the elements is nearly impossible.”

He recommends the incorporation of a website, The Elements: a Visual Exploration (http://itunes.apple.com/us/app/the-elements-a-visual-exploration/id364147847?mt=8) as a tool that links students to element-related technology. “The site is an iTunes app. A viewer can hover over an element and get a 3-D display of specific elements. It will also display some of the common ways the element is utilized. This is a tool that adds something real to the kind of abstract concept with which kids with disabilities often struggle.”

**Principle Three: Multiple means of engagement to tap into learners’ interests, challenge them appropriately, and motivate them to learn.**

“The third principle, which calls for multiple, flexible options for engagement, can, for example, encourage a teacher to challenge his/her students to design a system that uses solar power to improve some aspect of the students’ community. The students can use a virtual connection to link with scientists nationwide who are working on this problem. This
presents an opportunity for students to engage in a way that might not be available to them in a traditional classroom setting."

Games, Dr. Marino explains, are an effective way for students to access this type of engagement. He cites National Geographic’s “Resilient Planet” (http://www.jason.org/public/WhatIs/CurrORPIndex.aspx), as an example of an online game that enables students to explore real world problems. “This game has video clips of footage from the field. Students can follow the steps of scientists while they conduct their own experiments. The kids are actually working in a simulated environment in which they solve problems they’d never be able to solve or learn about from a textbook or in a traditional classroom."

An additional benefit, he emphasizes, is that this approach “is cost-free to schools. Ninety-eight percent of U.S. classrooms now have Internet access. These games are easily available and many encourage students to collaboratively work through the problems that occur during the course of the game."

**Research: Alien Rescue Was the Start**

Dr. Marino’s research, he says, began with a technology-enhanced STEM curriculum called Alien Rescue (http://www.edb.utexas.edu/alienrescue/). Alien Rescue, which originated at the University of Texas/Austin, was a project aimed at developing a month-long technology-enhanced curriculum to teach students about astronomy concepts. The curriculum, he points out, includes elements of engineering and mathematics and is entirely technology-based.

Alien Rescue, he explains, is rooted in problem-based learning and is geared toward middle school students. “At the beginning of the curriculum the students watch a 5-6-minute video where they learn that there are six alien species in another solar system who evacuated their home solar system because the system was failing. They are now in orbit around earth.

“The students, acting as scientists, visit a virtual space station housed on their computers – each student has his/her own computer. They use this virtual space station to learn about these aliens, about what the six species need in terms of their environmental requirements,
temperatures that facilitate the aliens’ survival, and the elements the aliens need in order to thrive."

The students, he continues, “employ their computers to learn more about our own solar system. Their task is to provide recommendations at the conclusion of the curriculum as to where those six alien species should go. There are multiple correct answers, but the emphasis is on using the scientific method to investigate the aliens and the solar system, examine a side-by-side comparison of the two and then formulate suggestions.

“I wrote a white paper in 2002 that reviewed Alien Rescue. In the paper I listed the aspects of the program that I thought were effective as well as those I thought ought to be improved. I heard back from a colleague of the woman who created the game. He told me the developers had just received a large grant that would incorporate all of my suggestions aimed at making the program more accessible to kids with disabilities. My suggestions were all based on Universal Design principles, although we weren’t using that terminology back then.”

During the ensuing two years Dr. Marino collaborated closely with the game’s developers to revise Alien Rescue by incorporating his UDL-based suggestions.

Taking the UDL Tools of Alien Rescue to the Next Level: More Games
Dr. Marino’s research has examined how students utilize the tools that were written into the program, including the UDL tools he recommended, such as an expert modeling feature. “I investigated how those tools were benefiting students with disabilities.” Specifically, he explains, he sought out a correlation between a student using the expert modeling tool and an increase in the student’s performance on outcome measures.

“We had a pre/posttest and also had six solution forms. Students completed a solution form for each alien, which was submitted after the students’ four-week investigation. The student input included what he/she learned about each alien, about the alien’s planet and a conclusion which included the students’ recommendation about which planet or moon was the most appropriate destination for each alien.”

Currently, Dr. Marino is working with researchers Drs. James Basham and Maya Israel at the University of Cincinnati and Filament Games (http://www.filamentgames.com/) to include UDL principles in video game development. “We are working with Filament to
develop science games aimed at enhancing curricula for kids with disabilities. “We’re also looking to take the Alien Rescue concept to the next level. Alien Rescue had 2-D attributes and some gaming features but it lacked a 3-D immersive environment; 3-D is the next level.”

One of the games he’s helped develop is part of a proposal, entitled Project Gametes: Games as Accessible, Multi-level Educational Tiered Environments, that will be submitted to the Institute of Education Sciences (IES) (https://www.iesabroad.org/IES/About_IES/aboutIES.html) next month. The proposal features a game that “puts a science student inside a cell, and in control of the cell. The kids are learning science vocabulary words and they can see what the endoplasmic reticulum looks like, for example. They can go into the endoplasmic reticulum and control what it does in the cell.

“In level one of the game the students learn the game’s basics and must demonstrate they understand how a cell functions.”

In level two of the game, he adds, students begin to encounter increasingly complex challenges within the cell. “For example, let’s say the cell has just been attacked by the N1H1 virus. How does the student deal with that attack? Each level of the game corresponds to national science standards and aids the teachers as a diagnostic tool to understand how the students are learning, because every time a student clicks or makes a choice within the game the teacher has a record that is directly linked to the child. The student, when he/she logs in, has an individual user name. When the student logs in; the teacher sees where the student stands in the game. When the child reaches the second level it means he/she has mastered all of level one’s standards. Teachers are able to view each step of progress.”

**Getting a True Measure of Knowledge: “Gaming Is about to Explode”**

Many assessments, he explains, falter in deciphering the reading/writing equation “because we don’t know whether a student’s performance on those assessments is a function of his/her actual knowledge or of the student’s inability to decode print or to write.”
In the cell game, he continues, “we can obtain a true measure of students’ knowledge, assuming that they are proficient and are able to use the game in the way we expect them to use it. For example, with a student who has a physical disability we make sure that he/she is able to cope with the physical demands of the game before we can begin to interpret the assessment data.”

Within this game context, he says, “students can go in multiple directions. They can choose their own challenges so that can engage in an activity that’s of interest to them, which is consistent with UDL.”

The game developers, he adds, “envision this approach as one that can be initiated in middle school because that’s where the achievement requirements increase exponentially.” Ultimately, he notes, the game will have practical use for students in high school and college as well.

“In chemistry, for example, the subject matter becomes even more complex than biology. The beauty of this game is that, in chemistry class for example, complex chemical reactions can be conducted with no risk at all to the students.

“If there is a student in class who has a breathing difficulty, for instance, and the teacher fears exposing that student to chemicals, or if there’s a student with ADHD who, the teacher fears, might place himself/herself in danger when conducting the experiment, this game dispels teachers’ worries because it is played on a computer. It’s all simulation. The research data shows that simulations are as effective as hands-on experiments. In fact, we have some preliminary research that shows that simulation is actually more effective for kids with disabilities than for kids without. Because of these factors I believe that the UDL-based gaming concept as a way to improve STEM achievement for middle school kids with disabilities is about to explode.”

Is This Technology Assistive or Instructional?

When asked whether he considers the technological aspects of technology-based UDL assistive or instructional, Dr. Marino replies, “It depends on the student. Much current technology can be assistive for some and instructional for others. My position, as well as that of other researchers with whom I collaborate, is that there is such significant overlap that the ‘assistive’ or ‘instructional’ labels
are often no longer important in terms of what’s best for kids and their classroom outcomes.”

Separate designations, he cautions, are necessary, however, “when referring to transition plans in which a child is using a specific type of technology that is assistive for him/her and that will be continued when the child moves on to a post-secondary setting and is covered under the Americans with Disabilities Act (ADA).” In that sense, he adds, the distinction is important. “I teach the secondary transition class so I’m sensitive to that point,” he notes.

However, he remarks, “in terms of teacher training and the development of technologies that are either assistive or instructional in the classroom, when I construct a universally designed lesson plan I consider only which technology will help to limit the barriers students with disabilities will encounter in the curricula itself.”

Something left to consider, he continues, “is that for students with the most severe low-incidence disabilities there will always be assistive technologies that are specific to their needs. We should not lose sight of that and it should be reflected in our universally designed lesson plans.”

However, he cautions, “when we consider the majority of kids in a general education classroom there is a significant overlap between assistive and instructional technology.”

**The Gender Factor in Technology-Enhanced UDL Materials**

In terms of the differences among students of varying ability in their response to technology-enhanced UDL materials in general, he notes that the performance of different students with different ability levels is based on the assessment that’s conducted. “I’m not convinced that we have sufficient evidence to say that one form of assessment is the best. In fact, I don’t think there is one form that’s best. There are differential effects based on students and based on assessments.”

A range of differences are visible, he says. “I wouldn’t expect to see predictable differences because each student brings his/her own set of individual circumstances and issues to the table. It would therefore be impossible to say that given X,
Y will happen when working with kids and attempting to discern how those students interact with the material."

One of the concerns when working with UDL materials and technology, he says, is that middle school boys, more than girls, appear to gravitate to technology. “Historically, that’s been the case. However, an emerging body of evidence suggests that this gap is narrowing, although we don’t yet have enough data to make a definitive assertion. A study I conducted that will appear this year in the Journal of Special Education Technology (JSET) found that girls outperformed boys in the Alien Rescue curriculum in a way that was statistically significant. We were surprised at that finding. We thought that the boys, because they played games more often, would be better at using the curriculum – but the study showed that they weren’t.”

**STEM Teacher Training in Technology-Aided UDL: Assuming a Coaching Role**

In conducting research that he says will be made public in the third quarter of this year, Dr. Marino and his colleagues recorded several revealing findings regarding the relationship between STEM teachers, technology-enhanced UDL and student performance.

The researchers examined teacher variables that they suspected would impact student performance, including: years of teaching experience; highest degree level achieved; years of experience teaching astronomy; and absence from the classroom, the one variable that had a statistically significant difference.

“When those teachers participated in the Alien Rescue curriculum, which is entirely technology-based, we gave each of them a very detailed teacher’s manual. Each underwent six hours of training with me. They read the manual on their own, then came together to use the program.” The teachers, in turn, taught practice lessons to their peers.

“As we went through the process most of those teachers expressed their comfort with the technology. However, my teachers who were further along in their careers were much more hesitant to just play with the program, and that was what we wanted them to do. In fact, when we conducted the pilot study we said, ‘Try to break this.’ This was the same challenge we issued to our seventh and eighth-grade Alien Rescue participants.

“In playing with the program the middle schoolers came up with fantastic recommendations and findings – but not the teachers, who were hesitant. Teachers need
explicit instruction. They need reaffirmation in terms of how to change their role. Most of these teachers were very comfortable leading the classroom. However, what we asked them to do in using this UDL framework was to provide direct instruction only when the students needed it. They assumed more of a coaching role, which is consistent with a teacher’s role at the secondary level. A secondary school teacher has done his/her job when a student graduates and does not need the teacher’s help anymore.

“When we provided the teachers with that type of instruction they were very effective. In fact, every day that the teachers weren’t there the students’ test scores – on a 230-point scale – went down 10 points.

“We learned that when we provided a very structured environment for the teachers they were able to learn about the technology in a non-threatening way. Providing the teachers with ongoing technical support was key for them to effectively implement the game in their classrooms.”

**UDL and the Teacher Time Factor**

Teachers love the UDL concept, Dr. Marino insists, but the time required to learn and implement it in classrooms has stunted its general acceptance.

“I teach special education teachers and general education teachers from under-grad final-semester seniors to the doctoral level and have taught UDL across that range. Although teachers favor the UDL concept they find its implementation to be very time intensive, which the research supports.”

Teachers also question how they’ll be able to implement it in the classroom on a daily basis, he adds. “It’s not realistic to say to our teachers, ‘Design lesson plans that truly represent Universal Design – but without the proper foundation.’ In my opinion, it takes 3-4 years of teaching the same content – and I’m speaking in terms of a full year’s curriculum – before the barriers to implementation become fully visible.”

Teachers require 3-4 iterations before they achieve a true UDL-formatted curriculum, Dr. Marino points out. “In UDL, teachers look at the curriculum up front, identify and consider all the barriers and then provide scaffolds to help students circumvent those barriers. There
should also be multiple means of assessment and multiple means for students to obtain information in the program. Inevitably, though, when teachers implement a UDL format for the first time it often doesn’t go the way they anticipate. Revision is then necessary.”

“Cool Tools”: Best Practices for STEM Teachers
Dr. Marino cites several examples of best practices websites that are useful for STEM teachers aspiring to teach in a technology-aided UDL environment. He calls the sites “cool tools.”

iTunes U (http://www.apple.com/education/itunes-u/) “has thousands of free videos, audio and podcasts. Entire college courses are presented on the iTunes U platform.”

WolframAlpha (http://www.wolframalpha.com/), an answer engine developed by Wolfram Research, “is a great website for math.” Voted the greatest computer innovation of 2009 by Popular Science, the search engine is an online service that answers factual inquiries directly by computing the answer from structured data, rather than providing a list of documents or web pages that might contain the answer.

Visual Dictionary Online (http://visual.merriam-webster.com/) “features excellent visuals of STEM concepts. If a teacher has a student who is struggling to understand how a cog might work, for example, the student can access that visual information on this site. Kids can hear audio pronunciations, contextualize references -- and the site is multilingual.”

Gizmos (http://www.explorelearning.com/) also emphasizes STEM concepts, Dr. Marino explains. “Users can access the site and experiment with it cost-free for 30 days after setting up a user name and password. The site is aligned with state standards. Teachers can explore the site and find the simulation that meets their lesson requirements. The objective is to create games that align with teacher classroom lessons in a way that enhances student understanding. The site has many simulations that are difficult to execute in the classroom. For example, teachers can access a multi-view, two-dimensional perspective of what occurs during an eclipse, a scenario that is difficult to construct in a classroom setting.”

PhET (http://phet.colorado.edu/index.php), developed by the University of Colorado/Boulder, offers interactive simulations.
Science Writer ([http://sciencewriter.cast.org/welcome;jsessionid=36DDA6D97E1F4C83862DB0F3423C405E](http://sciencewriter.cast.org/welcome;jsessionid=36DDA6D97E1F4C83862DB0F3423C405E)) supports students in writing lab and class reports. This tool is geared toward middle school and high school students.


Pasco ([http://www.pasco.com/products/probeware/pasport/Index.cfm](http://www.pasco.com/products/probeware/pasport/Index.cfm)) offers handheld devices that grasp and build items that are compatible with Pasco software. “These devices graph data that can be collected on teacher iPhones and then exported to a desktop computer.”

Google Earth ([http://earth.google.com/tour.html#v=1](http://earth.google.com/tour.html#v=1)) “enables users to go underwater, to see locations in time. Users can go to a place on the planet and then go back 20 years to see what it looked like then. For example, users can view the progressive recession of polar ice caps.”

Filament Games ([http://www.filamentgames.com/](http://www.filamentgames.com/)) “If viewers click on ‘Projects’ they can view the specific educational games that are included. This isn’t the World of Warcraft of 3-D computer games; these are educational games,” Dr. Marino points out.

Research Exposure: a Barrier to Implementation

Ironically, because Dr. Marino and his colleagues are often published in peer-reviewed journals, the lack of exposure to their research among practitioners is considered a major barrier to eventual implementation. “The research we’re conducting is not reaching the practitioners in a timely manner. We’re writing about the issues and publishing in peer-reviewed research journals because that’s our job. If I write an article for a practitioner readership and an article that is published in, for example, *The Journal of Mathematics and Science Teaching* that has only a 5% acceptance rate, the second article is awarded much more weight.”

He adds, “I believe we’re discouraged from writing practitioner pieces. This occurs
because we as researchers must publish in the research world."

Dr. Marino and his research colleagues receive most of their practitioner exposure via presentations at national conferences. “This year at the CEC (Council for Exceptional Children) conference Dr. James Basham from the University of Cincinnati and I put on a STEM presentation. Our hope is that CEC will give us a strand next year, or at least a pre-conference workshop. That’s when we can put these tools in teachers’ hands so the teachers can ‘play’ with them. Another way to achieve the same goal is through the NSF Friends Dissemination Center. That’s a way to get information out to those who need it and that’s the way federal agencies like to do it."

However, he cautions, the exposure his research receives through national conferences and other venues “will have little impact if it is not backed up by professional training within the schools."

The most effective way to provide that training, he asserts, “is to listen to the teachers needs and then have individuals like me visit a school, bring the appropriate tools and turn teachers loose to experiment with those tools. Then we’ll talk about the best ways to use those tools in a classroom.”

While worthwhile, necessary and prestigious, publication in peer-reviewed journals inadvertently promotes “horizontal growth and development,” he claims. “As soon as a way to do something is published readers then take for granted that that is the only way to do it. I find the same thing with my students. They want to know how to do something. I give them an example – and then they want to replicate my example.” Teachers, he remarks, “need to be encouraged to continually attend professional development trainings and then return and implement what they’ve learned in their classrooms. This promotes vertical change.”

Unfortunately, he adds, “the research I’ve seen on professional development tells me that there are not many models that are effective and efficient.”

Does he see a way to remedy that deficiency?

“That’s someone else’s research agenda,” he replies, with tongue in cheek. “There are many individuals looking at how to improve professional development. I wish them all
well. Their successes can only further acceptance and implementation of technology-enhanced UDL for STEM teachers everywhere, a goal which will continue to be dear to me."

When asked if his observations about technology-aided UDL for STEM curricula would apply to language arts and other non-STEM subjects, Dr. Marino replies, “My research has been so focused on tools that are effective for science, technology, engineering and mathematics that it would be impossible for me to say definitively that these tools would work in other contexts.”

Nevertheless, he concludes, “I believe that regarding the conceptualization of UDL, the teachers I instruct in my Masters level courses are able to apply much of what they learn to language arts in terms of the levels of support that technology offers. I believe, therefore, that UDL teachers and technology can be very successful in those other content areas. Specific tools used, however, may differ from those used in STEM curricula.”