The American Science Challenge

Game-Based Learning to Motivate Student Interest in Science, Technology, and Engineering

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Executive Summary

The American Science Challenge (ASC) is a program designed to improve student knowledge (and, consequently, standardized test scores) in science, technology, and engineering. The program is unique in that it focuses on improving student motivation and saving teacher time in the classroom through the use of video game techniques. The program was run in the fall of 2011 and the spring of 2012, with 10 Massachusetts schools and more than 1,000 students participating. JogNog, a competitive learning game, was used to implement the game-based learning techniques for improved motivation via a virtual world that was built as the students correctly answered standards-based questions in a fun but competitive quiz format.

Summary of Needs Before the ASC Program

The ASC was initiated by several teachers in the suburbs north of Boston to address the following issues:

1. Students were not motivated to take the Massachusetts standardized tests. Students are not aware of why the tests matter to them, and there are no easily accessible resources provided to teachers to help explain this point to their students.
2. Teachers routinely did not have enough time to cover all the standards that they were responsible for because they did not know which standards their students had already mastered and which they still struggled with. This often varied class to class, and even student to student.
3. Teachers cited "motivating students" as the number one barrier to being a great teacher, but they found it personally tiring and a drain of valuable class time to have to continuously find new ways of motivating their classes.
4. Teachers only had reports of standardized test results from previous years and did not know what types of questions, or even standards, their students already understood or were struggling with.
5. Teachers found that they were spending too much time in the classroom reviewing facts and rote material that could have been done at home or in self-paced study, leaving little time in class to address higher-order thinking skills and creative problem solving.
6. Classrooms were generally not equipped to provide one computing device for each student, so teachers needed solutions that students could do at home, on mobile devices, or in a group activity in class.

Summary of Findings After the ASC Program

Several surprising results emerged from the ASC program:

1. Students reported a change in attitude resulting from a change in understanding about the personal benefits of achieving a higher score on the state standardized MCAS test.

2. Some students in normally lower-performing cohorts were uniquely motivated by video games and were "reached" by the program, when they had not been affected in this way before.
3. Teachers could use the program for independent study that matched each student and provided skills at both the remediation end, as well as the enrichment end of the spectrum.
4. Using extrinsic rewards like stickers, posters, and ice cream for motivation had limited value and had to be carefully monitored.
5. Teachers' time was at a premium, and many competing programs were available to them. The ASC program had to be as simple and as intuitive to use as possible, requiring almost no teacher training.
6. Dedicated teachers were willing to spend significant amounts of personal time to investigate ways of improving student motivation.
7. Students self-motivated and cooperated, including using hours of their own free time to study, when fun competitions were initiated, especially when there was a greater team goal.
8. An assessment at the beginning of the school year was invaluable in showing teachers where each student and class was weak in their knowledge of the material stipulated in state standards.
9. A digital learning system like JogNog could save the teacher time by providing self-graded assessments and automatically generated review materials.
10. Teachers needed easy access to content that exactly matched their lesson plans and the state standards. The solution needed to be flexible and customizable to the needs of the teachers.
11. The quiz game format of JogNog had the added benefit of helping students learn good test-taking skills, especially for the multiple-choice question format that predominates in standardized tests.
12. Simple things like having students register for the game, log in, or find the right content are surprisingly difficult to execute smoothly. The learning game technology needs to be as simple as possible, yet controllable by the teacher.

The ASC is currently being executed in its second year with 50 participating schools in Massachusetts expected.

The American Science Challenge

> *"Motivation is such a huge part in what ends up differentiating student outcomes. Everyone has the ability to do fantastic work at a high school level. It's just without the right teacher and the right motivation, you don't always get there."*
>
> *–Bill Gates, Founder, Bill & Melinda Gates Foundation*

> *"Several years ago, it seemed like everyone recognized that the limiting factor for teachers had become time. It takes time to rewrite curricula for new standardized tests and curriculum standards. It takes time to incorporate technology. It takes time to differentiate. It takes time to build relationships with students. It's a deficit of time that holds teachers back."*
>
> *–Anonymous teacher post on an education blog*

Massachusetts, like most U.S. states, faces challenges with STEM (Science, Technology, Engineering and Mathematics) education. The occupational need for students well trained in STEM is growing, and STEM-related jobs are amongst the highest paying, yet student interest in STEM is waning. To combat this latter trend, the ASC (American Science Challenge) was created as an experiment to determine if game-based learning systems could be used to raise STEM knowledge in the eighth grade in select Massachusetts school districts. This increase was measured with standards-based assessments, as well as the 8th Grade Science and Technology/Engineering MCAS, which is the state's standardized test. The goals of the ASC were as follows:

1. To raise student STEM knowledge, resulting in improvements in the 8th Grade Science MCAS results
2. To support teachers with new technologies that help them to teach and motivate their students
3. To save teachers classroom time in teaching STEM topics with a simple, yet effective program that was intuitive and easy to use

The ASC was initiated via a collaboration of Massachusetts science and technology teachers and JogNog consultants to determine whether and how motivational game-based learning could be implemented by individual teachers in a way that did not require significant investments of training or class time. The ASC consisted of the following experimental program that was executed by individual science and technology teachers in ten Massachusetts school districts in the 2011–2012 school year. Participating teachers guided their students through the program in the following sequence (with approximate timing):

1. **October**
    a. Registered their students in the JogNog learning game and had them play a 70 question pre-program assessment to set a baseline of competence on MCAS science questions

b. Used the JogNog reports from the assessment to determine which questions and state standards their class was having difficulty with and used their lesson plans and JogNog quiz games to teach and reinforce that knowledge
c. Had students play the "Ace That Test" JogNog game, which helps students receive intrinsic rewards by understanding the importance of doing well on the MCAS test, as well as efficiently teaching them test-taking strategies

2. **November–March**
   a. Assigned JogNog quiz games that matched the standards being taught in class for a particular week as homework or class work
   b. Encouraged students to participate in the monthly JogNog MasterMind enrichment challenges, which independently motivates students to learn STEM content and other content based on state standards
3. **April**
   a. Had students use the JogNog learning game to play a 70 question post-program assessment using state-released MCAS science questions
   b. Used the resulting JogNog reports on the assessment to detect any final areas with which students were struggling so they could focus precious remaining preparation time on helping them learn those concepts
   c. Had students replay the "Ace That Test" JogNog game to remind them of the importance of doing well on the MCAS test

THE ASC WAS FOUNDED BY STEM EDUCATORS

In June 2012, three regional leaders of the Boston-based Museum of Science National Center for Technological Literacy, David Petty (STEM director, Winchester, MA), Richard Monagle (applied technology teacher, McCall Middle School, Winchester, MA) and Douglas Shattuck (applied technology teacher, Sanborn and Peabody Middle Schools, Concord, MA) approached JogNog to develop a curriculum dedicated to improving middle school STEM education. The teachers were interested in improving their abilities to use instructional technology effectively in and out of the classroom, as well as improving their students' scores on the 8th Grade Science and Technology/Engineering MCAS test.

THE JOGNOG EDUCATIONAL GAME WAS SELECTED

JogNog is a competitive game-based learning tool that can be played on the internet or via apps on any mobile device (such as the iPhone, iPad, iPod, Android, Kindle Fire, or Windows Phone). The student learns with JogNog by answering a series of multiple-choice questions that are presented in a simple game format of building towers and knocking down opponents' towers (see Figure 1). When presented with a multiple-choice question, the student clicks on the answer he or she believes to be correct. If the answer is correct, a new question is presented. If the answer is incorrect, the correct answer is highlighted in green. The student must click the correct answer to be presented with the next question. The student builds a tower level when he or she answers 80 percent or more of the questions correctly, and a complete tower when he or she has achieved mastery of the material. Typically, one standard from either the Common Core or the Massachusetts Frameworks is covered in each quiz tower.

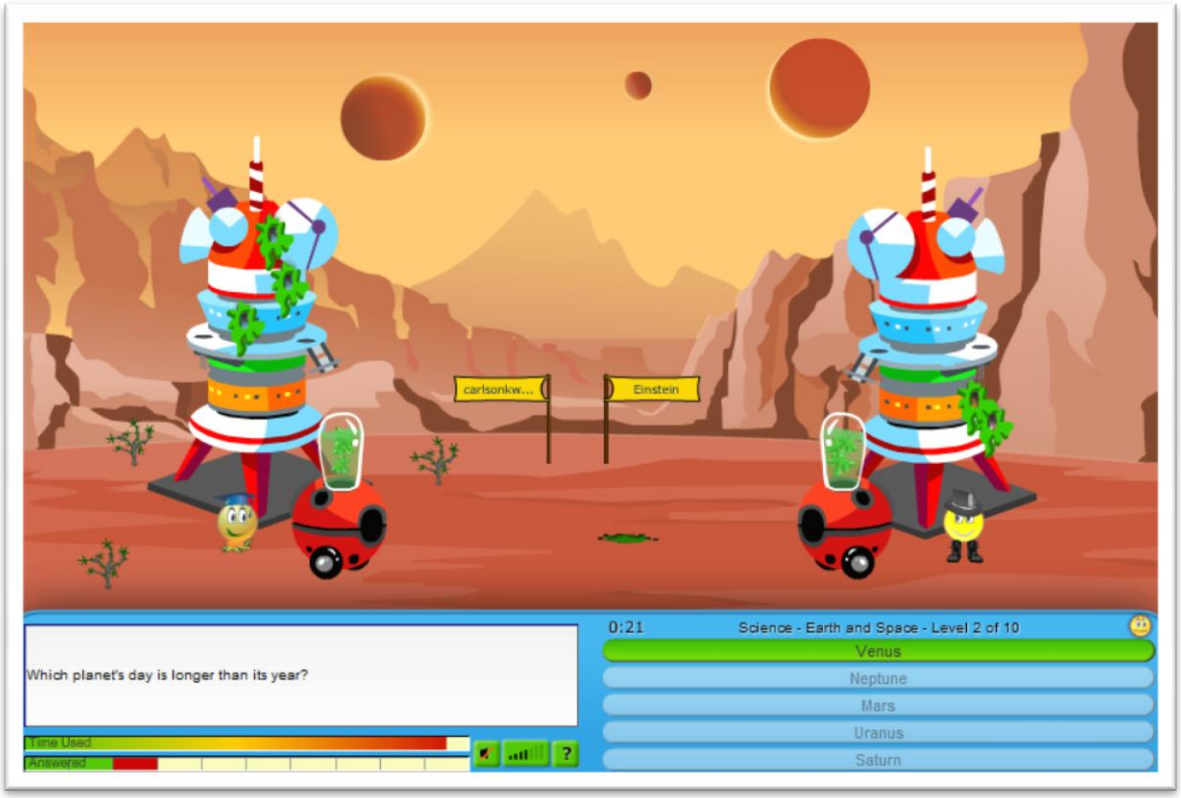


Figure 1. Format for presentation of a multiple-choice science question in JogNog. If students click the correct answer, they receive the next question. If not, the correct answer is highlighted in green and they must click it—forming an association of the question with the correct answer—to receive the next question. An algorithm presents incorrectly answered questions repeatedly until students have answered all the questions correctly.

A simple but important game mechanic of JogNog is the timer, which typically counts down from 7 minutes for each level of 10 questions (but teachers can adjust this setting if they wish). It notifies students of how much time they have left and is an important component of the game to keep them focused on answering the questions. A progress bar shows their progress toward completing the level, as well as the players' correct and incorrect answers. Incorrectly answered questions are repeated on each subsequent level until the students have answered all the questions correctly. Several of the key game mechanics are shown in more detail in Figure 2.

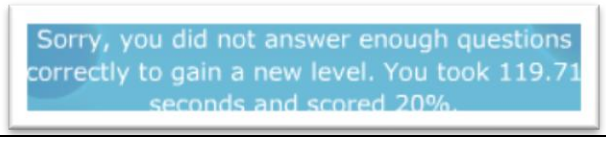
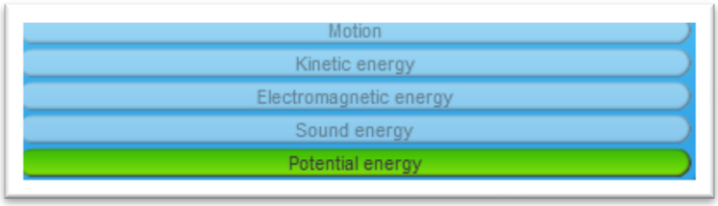
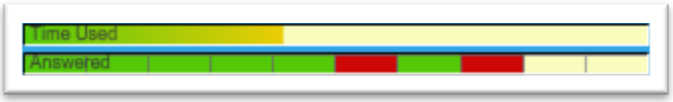
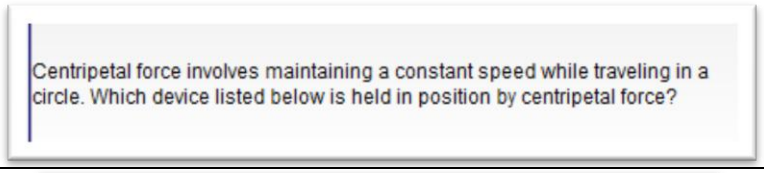
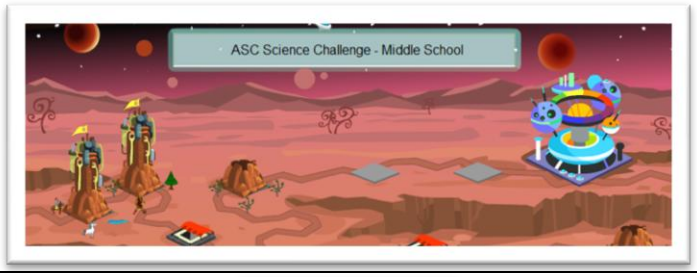
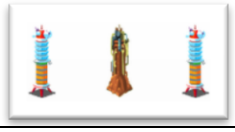
Game Mechanic	JogNog Game Example
80 percent correct answers are required to reach the next level. This encourages mastery before progression.	
The correct answer is highlighted in green when the student chooses the wrong answer. This enforces an association between the question and the correct answer.	
Elapsed and remaining times are tracked, along with the right and wrong answers. This keeps students moving and focused and shows them their continuous progress.	
Incorrectly answered questions are presented again to the student to assure mastery of even the more difficult topics.	
The "City View" encourages students to complete all content and provides a place to collect all of their "merit badges" (aka quiz towers).	
Completed towers for each completed quiz inspire pride of achievement.	

Figure 2. Game mechanics are used to achieve educational and motivational goals with the students.

There are many non-instructional game elements that are also important for increasing student engagement, thus increasing student knowledge. A leaderboard typically encourages game players to improve their performance by sparking their competitive nature. Thus, JogNog includes such a leaderboard, which can show all players or be filtered to show only the members of a teacher's class. Similarly, a student's motivation can be enhanced by showing his or her growing achievement, which is displayed in JogNog via such devices as the My Successes summary table, as well as a graphic display of the number of games begun and number of levels completed within them (see Figure 3).

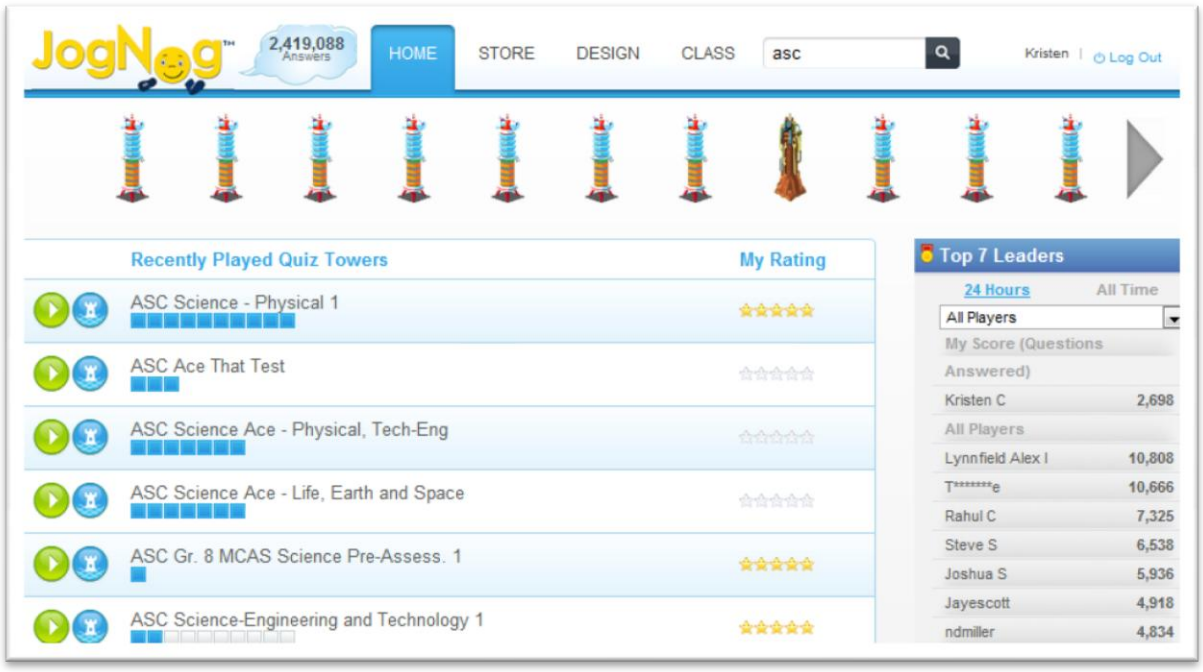


Figure 3. A typical JogNog student's home page depicting study games that she has played ("Recently Played Quiz Towers"), a leaderboard ("Top 7 Leaders"), various achievements ("My Success"), and other program features.

Teachers Must Be Confident in Content Quality

Teachers have rightly required that any educational technology first and foremost be of the highest educational content, not only in terms of correctness of fact, but also in terms of the strength in which the information is presented to the player. As a new field, educational technology runs the gamut when it comes to content, from crowd-sourced, user-contributed content to content that has gone through the same editorial and fact-checking processes as a textbook publisher would. Teachers often trust that the quality of educational game content is of the highest possible level, but this is not always the case.

There are many game-based learning systems available today that help students study by providing quiz questions or flash cards. Many of them, however, have user-generated content that students contribute for a particular class and share with classmates. User-generated content is valuable because it results in a large number of review questions, but it has two major disadvantages compared to more highly curated content:

1. The content is redundant, and it is difficult to find the appropriate content without having to create it yourself.
2. The content can be of low quality and filled with anywhere from subtle errors of perspective to egregious errors of fact, as well as a multitude of typos and misspellings.

The first disadvantage results in students wasting time trying to find relevant content—or creating it themselves—or redundantly learning the same thing over and over again. The

second disadvantage can result in time wasted in learning the wrong information. The solution to this is to have highly curated and edited content written by teachers who are expert in the subject and familiar with the grade level and teaching style. They create the most effective quiz and review questions.

JogNog-published content is at the far end of the curated side of the spectrum. All questions and answers (both the correct one and the "distracters") go through a structured, three-stage quality-assurance process. First, the questions and answers are created by accredited educators who are provided with a guideline document describing best practices for multiple-choice question and answer creation. Second, all questions and answers are edited by accredited editors, again with reference to the guideline best practices document. Third, an internal review of each question-and-answer set is performed as a final check.

How to Improve Student Motivation

> *"The larger cause of failure is almost unmentionable: shrunken student motivation… Students, after all, have to do the work. If they aren't motivated, even capable teachers may fail. Motivation comes from many sources: curiosity and ambition; parental expectations; the desire to get into a 'good' college; inspiring or intimidating teachers; peer pressure."*
>
> –*Robert Samuelson, economics columnist,* Washington Post

Game-Based Learning Is All About Motivation

If Americans were asked to identify the number one problem in the United States today, it probably wouldn't be education; it would be the economy. But as Secretary of Education Arne Duncan has pointed out, the two are one and the same: "The country that out-educates us today will out-compete us tomorrow." McKinsey and Co., the strategic consulting firm, makes an even bolder (if less optimistic) assertion—that the United States may have a "permanent recession," while those countries that are better educated than we are may well escape that fate.

What should be done about this alarming scenario, then? What is the single most important challenge in education today? What one thing would shoot us up the world rankings in a matter of months if we could only overcome it? Not enough computers in the classroom? Not enough standardized tests? No—the number one thing, as reported by the research of Robert Samuelson in the *Washington Post,* is student motivation. While the technology, the teachers, the textbooks, and the classrooms were all getting better, the students themselves were moving in the other direction. They were becoming less motivated. In 1984, 31 percent of 17-year-olds read every day, just for fun. In 2004, only 20 years later, only 22 percent were reading daily for fun, and that number has dropped again since then. If students don't want to be in school, they are hard to teach, and as Samuelson states, "Students, after all, have to do the work. If they aren't motivated, even capable teachers may fail." The techniques used to motivate players in video games might very well provide a solution if they are applied to education.

As educators, we have a tremendous opportunity to use the powerful motivators that video games provide, but we can't do it if we are afraid of failure. Video game techniques can be powerful and fun, as millions of students go home after school and experience them every afternoon when they play video games. The techniques just need to be applied in a way that allows students to learn as quickly and efficiently as possible.

Posters and Ice Cream Do Work…But…

One idea that JogNog used to try to improve motivation in students was to present teachers with large posters of blank landscapes, and sheets of stickers with images of towers on them (rendered using JogNog in-game graphics). Each member of the class would receive a sticker from the teacher following the completion of each in-game Quiz Tower. The student could

then initial the tower and adhere the sticker to the poster. Eventually, the barren landscape would become a crowded landscape of towers, the students proudly seeing the city on the wall grow in tandem with their accomplishment in the ASC. The poster was also designed to subtly encourage competition between classrooms, as students in one class would be able to compare the development of their poster-city to that of another class.

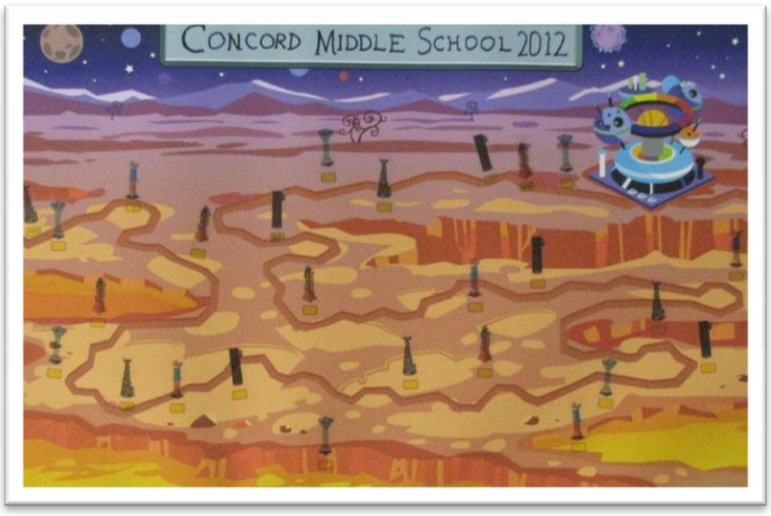


Figure 4. Achievement poster from Concord Middle School, Concord, Massachusetts.

Near the end of the ASC project, when teachers were struggling to get students to finish quiz towers, JogNog staff assisted them by offering students the incentive of a free ice cream upon completing a quiz tower. While this proved highly motivational to the students, it was initiated during the teachers' busiest time of year, just prior to the state standardized tests, and the teachers had little time to implement or track the distribution of rewards.

In the future, both of these motivational rewards will be simplified. Teachers also suggested that extrinsic rewards such as achievement posters and ice cream would be more powerful and effective if they were announced to students at the start of the program and used to enhance intraclass and interschool competition.

CAN WE CREATE SELF-INTEREST IN MCAS SUCCESS?

One of the things that we realized early on through teacher and student interviews is that overall, students have almost no motivation to care about the MCAS. They understand that it has no impact on their grade in class and little impact on their promotion to the following grade the next year. Students generally hold a negative opinion of the test itself, which may be reflective of parents and teachers who openly lament the overemphasis on MCAS (which they believe leads to "teaching to the test"), but then later on, they implore students to do well on the MCAS tests. Sadly, we were not able to detect anywhere on the Massachusetts state website anything that helped the teacher or the parent make a rational argument to the student about why the MCAS mattered to them.

This seems like a great opportunity, inspired by some groundbreaking research by Mesmin Destin and Daphna Oyserman. In their study, they showed that students were more than

eight times as likely to do extra credit homework if they were shown that their future occupation depended on school. They took two groups of low-income students from middle schools in the Detroit area and showed that almost every individual in both groups expected to attend college, but only half of them had a future occupational goal that depended on education (e.g., science, law, or medicine) as opposed to an education-independent one (e.g., sports or entertainment). But when one group was exposed to a lecture showing the opportunities of other education-dependent occupations, they were eight times more likely to complete an extra credit project than similar students who were not exposed to the lecture.

Given this remarkable results, we supposed that showing students why the MCAS standardized test could be of benefit to them might dramatically influence their commitment to doing well on the test. This idea was reinforced when one teacher independently volunteered at a monthly research meeting that she was having difficulty motivating her students to take the MCAS seriously. Her initial reaction was to enforce studying time for the MCAS, but she soon realized that this would have little impact if the students didn't care about the test. Often the students knew the answers, but they would just fill in answers randomly or they would get the numbers on the test and answer sheet out of alignment, thereby inadvertently marking the right answers, but for the wrong questions.

Instead of increasing either the carrot (extra credit points, ice cream, homework passes, etc.) or the stick (forcing them to study), she decided to take a short period of time to explain to the students why the MCAS was important to her, their school, and their community, and thus to them. She rationally explained its impact—and was shocked and elated at the difference in the motivation and behavior of her students in studying for the MCAS.

To use this research and the findings of this teacher, JogNog put into place a quiz tower entitled "Ace That Test." This quiz tower contained questions about good test-taking skills and preparation techniques. It also included questions that were intended to motivate students, such as questions detailing how education and test performance are required in a number of different vocations, and about correlations between academic performance and success and happiness in life.

Some of the quiz questions from the "Ace That Test" quiz game were:

1. Why is your good score on the MCAS important to your school and town?
2. Is it a waste of time to double-check your answers?
3. Why should you leave some extra time at the end of the test?
4. Higher test scores can help you to get better grades. What's the easiest way to boost your test scores?

JogNog did not know what to expect when the tower was presented to students, but their reactions were very intriguing. Teachers reported that students who played the tower felt more invested in the MCAS and expressed an increased desire to perform well.

In all, 163 users played the "Ace That Test" quiz game, and comments submitted by students as they played, as well as anecdotes, showed that the game had a positive effect on student motivation. One student, for instance, commented to his father before playing the game that he was more sophisticated and a simple game would not swayed his viewpoint that the

MCAS results would have no effect on him or his school or his future. After playing the game, he professed the same opinion, but he agreed that the game questions did bring up some important points. The following morning while preparing for school, he brought up the subject with his father without being asked, and he acknowledged that he now felt that the MCAS was much more important than he had previously realized and he wanted to get a better score on it.

CREATE A FRIENDLY INTERSCHOOL COMPETITION

JogNog MasterMind is an enrichment program that challenges students to answer as many questions as possible on a loosely unified theme within a certain time period. Developed contemporaneously with the ASC, JogNog MasterMind eventually became a possible candidate for use as a motivational factor within the ASC.

Students participating in JogNog MasterMind become eligible for one of two types of rewards. Individual students could earn a $10 or $20 Amazon gift card for being a top performer on a specific day of the competition, and then also for having a top overall score (i.e., number of correct answers). Also a trophy is awarded to the school whose participants have the highest combined score at the end of the contest period.

During the month of April the MasterMind competition contained content that supported the 8th Grade Science and Technology/Engineering MCAS which the students would take in May. The contest's theme was "Mad Scientist Month," promising participants a comprehensive overview of required middle school science content. The individual Quiz Towers were the sum total of the ASC Quiz Towers, except for the pre- and post-assessment material and "Ace That Test," with an additional Quiz Tower containing questions from the 2011 MCAS test.

Only schools of students involved in the ASC joined JogNog MasterMind in April, but the effect on motivation in those three schools was marked, with some students answering thousands of questions in the weeklong contest period. Students in Carlisle, MA, were particularly active in the competition, due at first to prodding from their science teacher, but later entirely on their own. Students began to watch the contest leaderboard to track their progress, and they began trying to outdo one another to secure top positions. When the Carlisle Public Schools won the monthly competition, members of JogNog's staff delivered the trophy to the school in person, presenting it in front of an entire grade of cheering students.

Though anecdotal, perhaps the most notable observation of all was that students in Carlisle appeared completely unaware of the individual Amazon gift card prizes and seemed consistently surprised to receive them. Yet the Carlisle students were the most enthusiastic about the JogNog MasterMind, both during the program and during the subsequent month of May, with participation dwarfing that of the other schools. In schools where the individual gift cards were emphasized, in contrast, students lost interest or became frustrated when they found it difficult to appear on the leaderboard and to secure prizes, and few of them returned to compete again in May.

In terms of motivating students to complete MCAS-related content for the ASC, JogNog MasterMind was an unequivocal success. In terms of encouraging students to continue learning beyond the scope of the ASC, the approach in Carlisle, in which the teacher was

actively involved in introducing the program to the students and the joint victory of earning the trophy for the school was emphasized, was by far the most successful.

Applying New Research on Motivation to School

Looking back over the various approaches taken by JogNog in attempting to motivate students, it is notable that the motivational rewards most closely related to academia itself—the intrinsic values conveyed in "Ace That Test" and the recognition of collective academic achievement on a schoolwide level in the form of the JogNog MasterMind trophy—appear to have been far more successful than extrinsic motivators that are not directly related to the process of learning, such as monetary rewards and ice cream.

In that way, JogNog's experience is consistent with a large body of research suggesting that extrinsic rewards are not valuable in improving long-term motivation and performance. For example, Lepper, Green, and Nisbett found in 1973 that young children who were told to expect to be rewarded with ribbons and stickers for drawing—and then were given those rewards—were less likely to play with drawing materials later than were children who had not expected the rewards. Similarly, a group of researchers led by Volpp (2008) found that participants in a weight-loss program showed short-term improvements if offered financial rewards for shedding pounds but exhibited no long-term differences when compared with participants who received no rewards. Perhaps most striking, however, is the incident reported by Rothe (1970), in which a group of welders suddenly found certain financial incentives removed from their work environment. Productivity initially dropped, but in the long term, the workers' output not only increased to their original levels, but actually surpassed them. More information about extrinsic rewards and reports about the cited studies can be found in articles by Alfie Kohn.

Taken together, these studies strongly suggest that, in the future, the ASC would benefit most from an emphasis on motivators relating to the act of learning itself, or that are otherwise intertwined with academia, rather than those that are extrinsic to the experiences of learning and education.

How to Save Teacher Time

> *"Ideally, I'd like the software to help teach and review the basics—the vocabulary and fundamental concepts of a new topic—and then use my class time for application, inquiry, and discussion to engage students' higher-order thinking and creative problem-solving abilities."*
>
> *–Dr. Kathy Marsh, 8th grade science teacher, Carlisle, MA*

Not Enough Time to Cover STEM Standards

Each ASC teacher participant had individual needs and goals for the program. An applied technology teacher was looking for a way to address his principal's concerns about lower-than-expected 8th grade MCAS test scores from the previous year. After analyzing the results, it became apparent that the students' scores were significantly higher in the technology/engineering strand than in the life science, earth and space science, and physical science strands. The teacher was faced with the challenge of only seeing the students twice per week and needing to cover all the technology/engineering material in that time. He did not yet have a way to also effectively review all the middle school science material that is tested on the 8th grade MCAS test. He and other technology-engineering teachers wanted JogNog to fill a gap in good curriculum materials and teach kids the basics so that they could use class time for hands-on projects such as building a bridge or a Rube Goldberg device using the six simple machines.

Another teacher was devoting much class time to prepare students for a science fair and wanted JogNog to address her resulting lack of time to teach more physical science, and like the teacher described above, be able to review material from previous years as well. Similarly, schools lacking an engineering/technology teacher or curriculum looked to JogNog to fill that gap exclusively.

Other teachers whose schools followed the standard sequence (6th grade—earth and space science; 7th grade—life science; and 8th grade—physical science and technology/engineering) wanted students to use JogNog to review 6th-grade earth and space science primarily, with the reasoning that students had forgotten more 6th-grade material than 7th- or 8th-grade material.

The common thread was that all the teachers aspired to teach their students the wonder and power of science and to add enrichment and advanced material. They considered teaching only to the standardized tests is a low bar to be avoided. But the single obstacle to their noble goal was lack of time.

The realization that individual teachers had specific needs but lacked the time to meet them added weight to JogNog's initiatives to create quicker, easier ways for teachers to find content and incorporate smaller units of it into their weekly plans by using shorter study games or those customized via the new quiz creation wizard (such as the JogNog QuickQuiz). To increase teacher efficiency further, study games were mapped transparently to underlying state standards and/or science topics.

Digital Learning Tools Must Free up Class Time

Initially, the design of the ASC program envisioned following the pre-assessment with a science curriculum, preferably encompassing all four strands (physical science, life science, earth and space science, and technology/engineering), since the 8th grade test encompassed all four strands. However, there arose an issue that is common to all efforts to add instructional technology to the classroom or homework: What work will be concomitantly omitted or displaced? Teachers plan their class and homework time to the minute.

Based on teacher feedback, three major internal development efforts were initiated to make JogNog content more readily accessible to teachers desiring to quickly find the content they needed to incorporate into unit planning. First, all content was to be reorganized according to a fine-grained, searchable taxonomy that would correspond to a guiding authority (such as state standards, where they existed, or an exemplary text or small group of texts). Second, all content would be reorganized into smaller study games. Each game would be just 10–30 questions rather than 100, and would correspond to a specific narrow topic, just like the section of a chapter in a textbook. Third, a test-creating wizard, QuickQuiz, was created so that teachers could create custom, topical quizzes in less than a minute.

It is also important that the simple logistics of getting students to use any educational technology needs to be as smooth and simple as possible. In many schools, difficulty in students logging in to an educational technology system can become a showstopper. In the case of the ASC, it was critical that the students easily find exactly the content that they should be working on, and have nothing else to distract them: "In my students' JogNog assignments, I want them to get to their assignment in one click and I don't want them distracted—they should only see that assignment. And I need to be able to change assignments easily," said Rich Monagle from McCall Middle School in Winchester, MA, ranked #5 in Massachusetts in 8th grade science scores. Accordingly, JogNog developed a Class Secret Code, which, entered into any search box, immediately showed the student's assignment. This also saved the teacher's time, as he or she did not have to upload, type in, or even invite the students to the virtual classroom. Instead, the teacher just wrote the secret code (e.g. "130JHI4") on the board at the front of the class, and each student could independently join the right virtual classroom with no more effort from the teacher.

Support the Differentiated Classroom

Almost all teachers find the modern all-inclusive classroom challenging. Teachers are induced to split their time between the majority of students and the minority who are struggling with the subject matter. Ideally, teachers would like instructional technology to help them engage diverse student personalities and abilities without slowing the class down to accommodate all students. Using elements of commercial video games that have been proven to engage young people, a competitive educational video game comes close to this ideal. Teachers in the ASC found that JogNog broke up the normal routine and provided a new way to present science that engaged most, if not all, students. During JogNog sessions, teachers could turn to other activities while monitoring students' progress with the completion report.

Perform Rote Learning Outside the Class

Holding up his iPod at the Concord High School library in September 2010, Tony Wagner, author of *The Global Achievement Gap,* stated, "The value of *what* we know has fallen dramatically. I can Google facts in seconds on my PDA. It's *how to use what we know* that we need to teach kids to prepare them for the globally competitive environment."

Consequently, more and more teachers are looking to instructional technology to take over the burden of students' rote learning. Moreover, they look to the technology to perform this essential prerequisite more efficiently and less onerously on the student than antiquated methods. In short, they look to technology to replace class and homework "drill and kill" with something more futuristic.

A software program using video game mechanics to engage kids and spur them on toward mastery, as well as algorithms to ensure the proficiency standard set by the teacher, fits the bill. For example, rather than expending class time learning the definitions of basic mechanics concepts such as *force*, *mass*, *position*, *velocity* and *acceleration*, or even Newton's laws, a physical science teacher would prefer that students come to class with the definitions under their belt, fully prepared for him or her to teach them the significance of the concepts and how to use them to solve problems.

A rigorous experiment of focusing class time on problem solving and higher-order thinking skills has been conducted at the collegiate level with spectacular results. At the University of British Columbia, a team led by Nobel Prize–winning physicist Carl Wieman took aim at the traditional chalk-and-talk approach to teaching. Team members Dr. Louis Deslauriers and Ellen Schelew used the technique of "deliberate practice," where class time is spent on problem solving and building intuition and students read the material and memorize facts before they come to class. For 850 students taking a compulsory physics course, the difference between "traditional lecture" and "deliberate practice" was 41 to 74 percent. Deslauriers cited this as the "biggest performance boost ever documented in educational research."

The research that lies behind JogNog supports deliberate practice and aids the teacher in transferring the memorization of facts and content to the home so that students can focus on building higher-order thinking skills in the classroom. We recommend that JogNog be used by students at home, as they read a new textbook chapter, and that classroom time be used to weave that content together. With motivation provided by the game, JogNog encourages students to become exposed to material before the teacher presents it in class. The preliminary results of JogNog research are confirming what Deslauriers discovered: dramatic increases in speed and quality of learning.

Game-Based Learning Assesses as It Teaches

The teachers wanted a short pre-assessment test to implement early in the school year. Accordingly, G7 Research built two one-level, 35-question study games for pre-assessment. Each game contained two of the four strands (earth and space science, life science, physical science, and engineering/technology).

Further, a principal who was brought into a school struggling to improve STEM education, Arthur Unobskey of Washington Irving Middle School, told JogNog, "I need frequent, relatively noninvasive assessments to tell my teachers if their instruction is on track to reach our goal of moving 10 percent of our kids out of Warning/Failure and Needs Improvement and into Proficient." Thus, Principal Unobskey articulated a key component of the program: assessments that teach as they assess, rather than assess only, which subtracts from class time.

Several strong advantages emerged as a JogNog assessment mode was analyzed, and the pre-assessment met the goal articulated by Principal Unobskey for minimally invasive assessments. First, even in assessment mode, whether students answer a question correctly or incorrectly, JogNog requires them to make a positive association between the question and the correct answer. Hence, JogNog teaches as it assesses, unlike printed assessments.

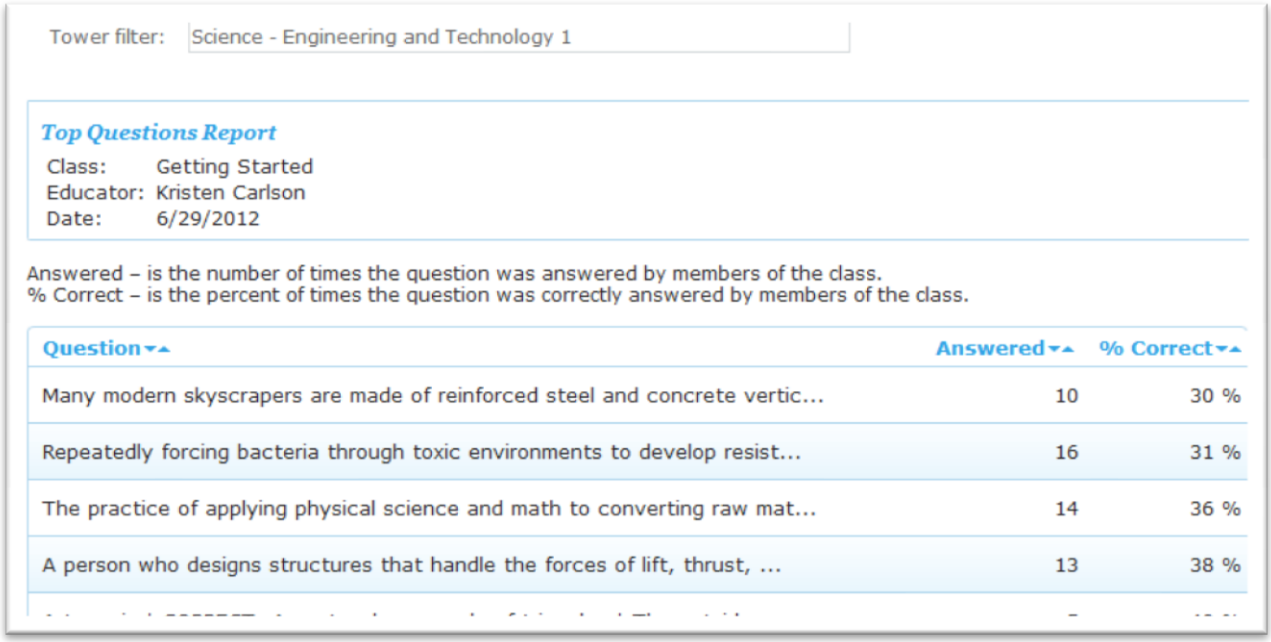
Second, real-time electronic compilation of student completion of the assessment and ranking of the questions with which they struggled the most proved to be valuable time-savers for teachers, who are always striving for efficiency and freeing up time for more productive use. As compared to hand-correcting, printed, consumable tests, an electronic compilation seems an inevitable way of the future.

KNOW WHAT STANDARDS YOUR STUDENTS ARE MISSING

The JogNog Top Missed Questions report ranks, in real time, the questions answered by students according to the percentage answered correctly. Thus, by sorting the correct answers from 0 percent up, the teacher can easily see for the class—or, by filtering, for a specific student—the questions with which the class or student is struggling (Figure 5).

One teacher used the Top Missed Questions report to great purpose. Doug Shattuck divided the questions his students missed into two groups: those covering material that he had not taught versus those covering material that he had taught. He was then able to discern when he was presenting material that the students were not learning and he was able to change and improve his class instruction. "If I've taught them something, and they're missing it, I'm doing something wrong and have to find a different way to teach that material," he noted.

An example of concepts that weren't getting through to the kids in Shattuck's 8th grade applied technology class was encoding and decoding in communication theory. To expand students' knowledge of these concepts, Shattuck incorporated into his lesson more examples of encoding and decoding, such as Morse code and signal flags used by yachts entering a harbor. He even bought an antique set of U.S. Army semaphore flags to demonstrate encoding and decoding in class.



Tower filter: Science - Engineering and Technology 1

Top Questions Report

Class: Getting Started
Educator: Kristen Carlson
Date: 6/29/2012

Answered – is the number of times the question was answered by members of the class.
% Correct – is the percent of times the question was correctly answered by members of the class.

Question	Answered	% Correct
Many modern skyscrapers are made of reinforced steel and concrete vertic...	10	30 %
Repeatedly forcing bacteria through toxic environments to develop resist...	16	31 %
The practice of applying physical science and math to converting raw mat...	14	36 %
A person who designs structures that handle the forces of lift, thrust, ...	13	38 %

Figure 5. The JogNog Top Missed Questions report, sorted for the most-missed questions, which shows the subjects that students are struggling with.

Improved STEM Education Next Year

> *"We can't imagine any cause more worthy of our efforts than to assist our teachers in motivating the passion of students for Science, Technology, Engineering, and Math. We seek to provide educational technology that makes the daily life of a teacher simpler, easier, and filled with more time to focus on the enrichment and highest educational aspirations of their students."*
>
> *–Stephen Smith, Co-Founder and CEO, JogNog.com*

If you have read this far, you realize that we have used a particular educational game (JogNog) to motivate students and save teachers time as part of the ASC. Because we are the creators of JogNog, we obviously have some pride of ownership here. That being said, however, there are many other educational technology resources that could also be used in this way, and the best practices that we have shared within this report can be used in your classroom today, with or without JogNog. For instance, it is easy to create posters and hold fun, interclass competitions solely with paper quizzes, or to take time out of your class to rationally explain why STEM knowledge is beneficial to your students and why their results on the Massachusetts Science MCAS test matter to them, their teacher, their school, their parents, and their town. These techniques provide outstanding results that are facilitated by game-based learning, but they do not require it.

By working closely with teachers, we also saw several improvements that could be made to the program the next time it gets implemented with JogNog. These will be used with the ASC in 2012–2013. In order of priority, here are improvements that we are making, which may be of interest when implementing such a program at your school:

1. There will now be a single JogNog quiz tower for each individual standard in the Massachusetts Science Frameworks, and, upon adoption of the U.S. Common Core or Next Generation Science Standards, to those individual frameworks as well. This will make it very easy for teachers to select only the relevant content on Science, Technology, and Engineering that matches their particular lesson plan for that day or week.
2. Teachers will also have access to a new tool called JogNog QuickQuiz, which will allow them to construct quickly (that is, in under 60 seconds) new quiz games that encompass several standards. Each game can be played for review in class or at home, and it can also generate a printed quiz that can be used for summative assessment in class.
3. A summative assessment (test) mode has been added to JogNog so that it is easy for students to move through the quiz games without having to repeat long MCAS questions that they have already answered.
4. A new report has been introduced, which concisely shows both summative assessment scores (test results the first time they play the quiz game) and mastery level. This is helpful in that it motivates the students to focus and take more seriously getting the most answers correct on the pre- and post-program assessments.

5. The "Ace That Test" quiz tower will be presented to students early in the program so that they build intrinsic motivation for learning STEM standards and take pride in performing well on the state's standardized test (the MCAS).

ACKNOWLEDGMENTS

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ABOUT JOGNOG

JogNog provides competitive video games that motivate kids to learn in an engaging and fun way. Specifically designed to meet teachers' needs in addressing standard curricula for grades 2 through 12, JogNog uses the latest in educational research to create competitive learning games that motivate and engage students. To receive future research reports as they become available, subscribe to the JogNog newsletter at *www.JogNog.com/newsletter*.

How to Join the 2013 ASC

If you are interested in participating in this year's ASC, please visit *www.JogNog.com/Study-Guide/ASC.html* for more information. A limited number of schools will be accepted into the program. Qualifications for acceptance include:

1. Willingness to execute the program so that research data can be collected.
2. An internal champion teacher who will attend online and dinner meetings every other month to share best practices.
3. Relevant grades and interest, including:
    a. Massachusetts 8th grade classes about to take the 8th Grade Science MCAS test.
    b. Massachusetts 6th, 7th, or 8th grade classes wishing to focus on STEM content.
    c. National or international students looking to use the excellent Massachusetts curriculum and the new standards in science that will be available shortly.
4. Application for scholarship. There are a limited number of scholarships available for first-year members.

This white paper can be found at: www.JogNog.com/Documents/ASCWhitePaper2012.pdf

APPENDIX 1:
ASC PARTICIPANTS

Teacher	District	School	Number of Students Participating	Total STEM Questions Reviewed
David Petty* Richard Monagle* Thomas Awiszcus Thomas Sterling	Winchester, MA	McCall Middle School	298	36,998
Douglas Shattuck*	Concord, MA	Sanborn and Peabody Middle Schools	133	6,498
Jennifer Heintz	Waltham, MA	McDevitt Middle School	155	43,960
Courtney Delaney	Lynnfield, MA	Lynnfield Middle School	146	23,285
Shelby Soloff	Roslindale, MA	Washington Irving Middle School	85	5,794
Meaghan Dempsey	Revere, MA	Garfield Middle School	24	1,494
Heather D'Ambrosio Paul Suitter Adam Rizzo	Revere, MA	Susan B. Anthony Middle School	142	23,100
David Lawrence	Lexington, MA	Jonas Clarke Middle School	44	7,742
Kelly Graveson	Douglas, MA	Douglas High School	96	14,609
Kathryn Marsh	Carlisle, MA	Carlisle School	70	8,524
		Total	**1,193**	**172,004**

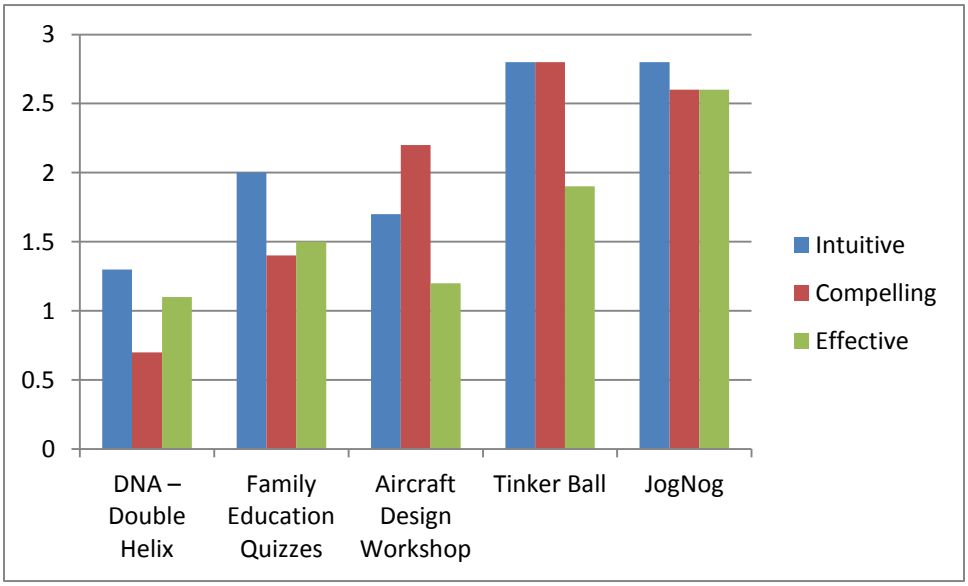
**Founding educators of the ASC*

APPENDIX 2:
HOW TO FIND EFFECTIVE EDUCATIONAL SOFTWARE

While all teachers—and especially STEM teachers—believe good educational software exists, they frequently hear students say that educational software is boring. Boring software is bad enough, but boring software that is ineffective is even worse. One of the founders of the ASC, Douglas Shattuck, has developed a rubric for rating educational websites. Shattuck's rubric uses three metrics: Intuitive (easy to learn), Engaging (interesting to play), and Effective (succeeds in teaching)—ICE for short. Shattuck asks his students to rate a selection of educational websites according to the rubric each year, and he reports that these sessions are some of his students' favorite classes.

As rated by students' ICE rubric, JogNog scores high against other educational software. JogNog is designed primarily to teach, and to teach very efficiently on top of it.

Much of the extensive research on teaching and learning science and technique, as well as on video games, is available via the JogNog Weekly email, which is archived on the JogNog blog.



Using the ICE rubric, students rated five educational websites in August 2011.

APPENDIX 3: STUDENT PARTICIPATION AND COMPLETION

JogNog Quiz Game	Questions in Game	Students Who Played	Questions Answered Correctly	Average Student Score First Time*	Students Who Completed Quiz Game
Pre-Assessment 1	35	842	15,797	60%	86%
Pre-Assessment 2	35	811	13,405	54%	87%
MCAS Science 1	46	408	7,587	65%	82%
MCAS Science 2	45	404	3,102	64%	31%
MCAS Science 3—Handout	36	26	234	50%	53%
MCAS Science 4—Handout	38	393	1,545	34%	24%
MCAS Science 5—Handout	26	23	186	38%	83%
Earth and Space	100	195	5,603	54%	57%
Life 1	100	64	916	48%	34%
Life 2	100	15	173	48%	24%
Physical 1	100	119	2,726	49%	48%
Physical 2	100	30	628	73%	30%
Science Engineering and Technology 1	100	533	13,165	43%	60%
Science Engineering and Technology 2	100	414	14,828	65%	60%
Ace That Test	32	149	3,135	81%	86%
Science Ace—Life Earth & Space	35	213	3,889	63%	85%
Science Ace—Physical Tech-Eng	35	266	4,881	57%	91%
Total	**1,063**	**4,905**	**91,800**		

** Based on the correctness the first time the student answers each question.*