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Distinction Project Methods Paper

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What and Why: Building 6thgradescienceexploration.com

Abstract:

We created a website focused around the Virginia Standards of Learning for sixth grade science, with the purpose of creating more interactive work for students to explore. This website exists at http://6thgradescienceexploration.com and contains six modules that touch on each category of the Virginia SOLs for sixth grade science. It also contains mathematics and writing worksheets that are built to go along with each module, which address several of the sixth-grade math SOLs. All material within and outside the modules is differentiated to reach students at different capability levels, without changing the science content covered. There has been interest expressed by educators in two different school districts to use this website within their classrooms, both for review before the eighth grade SOL exam and for English teachers in a STEM focused school district.

Introduction:

We have created a website that is a tool for early STEM education that can be used by teachers and students to promote the understanding of, and interest in, STEM subjects. We have focused on sixth grade science, which is grounded in fundamental concepts that are the backbone to all science disciplines. This project was selected due to the common lack of STEM background in many educators, especially at the earlier levels (Bransford). As of 2013, only 41% of middle school science teachers had at least a bachelor's degree in a science, engineering, or

science education field (The National Academic Press). This website is a tool to provide a starting point or extension for teachers to help create increased engagement in the science classroom.

This project is focused on the Virginia Standards of Learning (SOL) for sixth grade science. While the Common Core State Standards are not specifically addressed, the Virginia SOLs for sixth grade meet all current federal standards, which means this website could also be implemented in Common Core states. The mathematics standards in Common Core focus on the same content as the Virginia SOLs, and although there are no specific science standards in Common Core, the Science and Technical Subjects subsection of the English Language Arts standards do fit within this website's structure (Common Core State Standards Initiative). We have also chosen to focus on the Virginia SOLs as we have connections to local teachers who have indicated interest in using our website.

We have structured this website to be interactive, pulling concepts from the educational strategies of problem-based learning, anchored instruction, and problem-based science formats (Bransford, Hmelo-Silver). These systems all share a student focus and emphasis on problem solving skills, instead of just fact-based learning (Hmelo-Silver). Problem based learning allows students to address presented problems in creative manners that may reach several different, correct solutions, and emphasizes student reflection to drive the learning process. Anchored instruction allows a presentation of facts that pertain to the problem at hand and provides tools for the students to use to help them solve the problem. Scientific exploration focuses more on the scientific process by making observations and predictions, and then finding explanations for the way things work; it is centered around a question instead of a problem. Used in conjunction, these three methods allow for a structure that gives students an opportunity to meaningfully

explore and engage with course material (Hmelo-Silver). Further, this type of exploration has also been shown to provide a stronger sense of curiosity and passion for learning in the target age group (Atkinson 62).

Current STEM education is often focused more on the acquisition of facts, but critical reasoning and the ability to problem solve are skills that students need, both within STEM fields and outside of them (Madden). The above methods differ from traditional classroom education due to their focus on problem solving and critical reasoning skills. Within the greater STEM community, research suggests that problem-solving skills and creativity will lead to future innovations as the students eventually move into the workforce (Madden). Our website is a tool to enhance students practical skills while incorporating essential information as required by the Virginia SOLs by containing a blend of different question styles from reading comprehension to observations and predictions to addressing real world problems.

This website is also designed to reach a wide array of students. The same science material is differentiated to reach students who are below, at, and above grade level in reading. Differentiation is "a systematic approach to planning curriculum and instruction for academically diverse learners. It is a way of thinking about the classroom with the dual goals of honoring each student's learning needs and maximizing each student's learning capacity" (Tomlinson, Strickland, 2005, 6). This practice of differentiation is a valuable one, especially as classrooms become more diverse. Doubet and Hockett (2015) note that, "differentiation articulates how the classroom teacher makes important curricular goals accessible to all learners within the same classroom" (p. 2). By having the same science content delivered in three different reading levels and with varying degrees of scaffolded support, we are seeking to meet the needs of a wide range of students that we see in the modern classroom (Robb, 2003).

Methods:

In the first semester of work on this project, research was done with Dr. Lisa Stoneman of the education department. The goal of that independent study was to learn the appropriate education theory pertaining to the way the website should be structured. Some of the important topics that were covered were how to incorporate scaffolding into curricula, how different students engage with material specifically in the science classroom, the importance of inter-curricular learning, and how problem-solving instruction differs in execution and long-term outcomes from traditional memorization of facts. From this study, a better working understanding of how to approach the curriculum that needed to be built was developed.

The outlines of the modules that would populate this website were started, though they were far from complete at that point. The vision had been to create eight modules that would have multiple correct answers to some quite complex scientific questions for the sixth graders. This process started by looking at the Virginia sixth grade SOL outline and searching for connections between SOL categories. Clumping a few of these sections together lead to broad ideas for questions that a module could focus on, while touching different ideas. Six module topics were selected, covering all of the SOL categories, with most pulled into at least two separate modules. The other two proposed modules were left unfilled with the intent to fill them upon receiving feedback from local teachers.

In the second semester of work on the project, an independent study was taken with Dr. Durell Bouchard in which the basic concepts of web programming were covered. Through several online instruction programs, the basics of two essential web programming languages, HTML and CSS, were learned. After a few months, there was a working understanding of how to put together basic web pages, and the website was ready to look a little more professional. At

that point, the only development was a home page and the skeletons for other pages whose incorporation was unclear. The use of Bootstrap was integrated into the code such that the website would have a cleaner look and feel. With that, the modules home page was able to be built out almost to where it was desired. Halfway through that second semester, focus was shifted to making a drag and drop question work, and on some artistry and click-interaction questions.

Each of those tasks required learning JavaScript and jQuery programming languages in order to be able to make the pages interactive. The desired interaction of clicking and dragging involved having to learn how to program an image to be draggable, and how to create a landing spot for the dragged images. Creating a helper friend, reminiscent of Clippy from Microsoft Office ‘97, resulted in the website helper, FlaskMan. Additionally, some other artwork for the website was developed. For the click interaction pages, a similar approach to the drag and drop interaction was taken by using gold boxes to surround an image as an indicator of whether or not something was clicked (it turned from gold to green upon clicking it). Then, the FlaskMan was added into each of the module pages that had been created at this point, and he was given the ability to be interacted with. He serves to provide students with hints, which change with each question presented. These hints are determined based on the parts of the question that have already been answered.

The verification process at the end of each question page is done by use of a dictionary. This structure was created with the first module, focused on river system. This verification system is set up so that students have to have a correct answer to move forward in the module. If a student hits the submit button without a correct set of answers, then the FlaskMan provides the appropriate hint for the student to see what needs fixing.

The first module's pages would become the basis for all of the modules that would be built in the future. It was then realized that, incorporating the free-response style that had been originally desired would not be feasible, as it would be quite difficult to parse out what makes a response to the question correct or wrong. Instead, it was opted at that point to include worksheets for students that teachers could grade. At the end of the term, the change to using PHP files instead of HTML files for each of the pages was introduced. This system allows for more flexibility in the structure of the code but is a bit more complicated to use.

In the third semester, another independent study with Dr. Stoneman was taken, which was focused on simplifying as much of the code as possible and set up a timeline to finish the project in the fourth and final semester of work. As such, that semester was focused on fleshing out the rest of the modules content, converting all of the files into PHP files, and converting the first module into a template so that the rest of the modules would be streamlined from the process standpoint. Considering that there was only one out of six modules functioning at this point (equating to about 30 more pages that would have had to be made), that simplification was very appealing.

Laying out the rest of the modules page by page was done in a handful of sessions, where the original topics that had been selected were laid out on different pages. Then, keeping in mind the want to minimize the introduction of new data structures and coding techniques, each question for each module was generated to largely fit into the drag and drop or select all that apply formats. There were pages where animation was to be used, which was kept, as that was a skill that felt manageable to learn. However, the idea of multiple correct answers was not kept, as the coding for this was far more complicated than the skills thus far acquired could handle. The module count was also cut down to just the six whose topics were already selected. By the end of

this process there was a layout of each question on each page for each module and an accompanying sketch for the imagery that would be used. There was then a verification process that the desired SOLs were in fact covered, and a write up of the process of each module was made for the For Teachers page of the website.

The next task for the semester was to learn the new language, which was done with help from Scotty Smith. By Fall Break, the basics of PHP were covered, and all existing HTML files had been converted to PHP files. This resulted in a working template for the 'select all that apply' style questions and the 'drag your answer to the location' style questions, which now accounted for most of the other module's pages.

In the second half of the semester, each of the pages were linked together through links displayed on the page, and also upon successful completion of each of the pages. That is to say that if a student got a question right on one of the pages, they would be successfully passed onto the next page in a module. The rest of the pages were also created, all using the PHP format, though not all of them were fully populated. The coming term would include shipping the website to a live server, and the plan had been to incorporate a way to send emails to teachers to inform them of how their students had progressed through each of the modules. This was something that was then set as an "if there is time at the end" system. At that point, there was a truly skeletal form of what would eventually become the finished website.

For the final semester, there has been a lot of finishing work on the website to get it to where it was envisioned. Again, an independent study was done with Dr. Stoneman. There were several module pages that had proposed animations with them, so that was the first priority for this semester. First, an understanding about the canvas functionality within the context of HTML was undertaken, where the development of a windmill for the energy module (module 3), was

built with the guidance of Scotty Smith. From that HTML file, a PHP file was made. Using that as a template, the construction of a car and a rocket for use in other modules was accomplished. Each object was given the illusion of moving across the page via the use of a moving number line to indicate the distance traveled.

After the animations were pinned down, work shifted to content creation again. This was done with an introductory reading passage for each page, which introduced concepts and vocabulary to the students, which will give them the background for the rest of the module. These have three different versions, an idea which came from the teachers who were presented to last June at the Copenhaver conference, who wanted a system they could use with their English Language Learners and other students who may be below grade level in reading. Vocabulary exercises, which function as a reading comprehension check for the introduction page in each module were also created. These are structured as a fill-in-the-blank section that appears directly beneath the reading section. The reading passage was built from looking through the primary vocabulary used for the different SOL sections and seeing what had been used in the module. The decision was made to repeat vocabulary terms that were used in several modules, in case a student wanted to go through them out of order. Both Dr. Stoneman and Mary Jo Heckman, a sixth-grade teacher and former reading specialist, provided insights on how to construct these reading passages and how to differentiate them for differently skilled readers. Mary Jo has worked in the Harrisonburg City School District for 30 years, where only 54% of students were born in the United States and 58 different languages are spoken by the student population as of 2017 (Enrollment of English Learners). This made her an incredible resource in learning how to make material for ELL students, as well as the intermediate and advanced students, who are still

well represented within Harrisonburg City Schools. The reading comprehension questions were made directly from the reading passages with which they are paired.

Since Spring Break, writing and math worksheets that go along with each module were generated. These also have versions for students who may be below grade level to accommodate the wants of the teachers we have spoken with, as well as advanced versions of the writing prompts for students who are more advanced than their grade level. These were linked in the 'For Teachers' page, where the outline of each module was also added. The writing worksheets contain one to two essay prompts, that can be answered in about a paragraph. The beginner level contains a word bank and sentence starters as scaffolding for struggling students. The intermediate level contains only the word back for assistance. At the advanced level the students are just given the prompt without any aids in how to answer the questions. The prompts are all connected to the content of the modules with the intent to push students to articulate their learning and strengthen their communication skills. These were made with the guidance of Mary Jo Heckman. The math worksheets were similarly constructed to build on the concepts in the modules, and to try to help the students see the integration between mathematics and science. These were made at two different levels, a beginner level where the multi-step problems are broken down into single steps, and a standard level where the students have to break the questions apart on their own. These worksheets are mostly focused around the sixth grade mathematics SOLs, and were made under the advising of Chuck Heckman, a retired elementary and middle school mathematics teacher who has also spent much of his career within the Harrisonburg City Schools, as well as working with the remedial math students in Rockingham County.

Clean-up work was then done on the website in order to ensure that everything worked properly. That work included checking the links for each of the pages to ensure that they were properly connected to one another on completion, making sure the formatting on each of the PHP pages was as similar as possible to make future changes simpler, and removing large sections of code which were no longer being used. Additionally, the images were created and found for each of the pages, which came from ClipArt, available online for free, as well as from an artist recommended by Dr. Poli. After that, the number of pages was nearly tripled in the website by dividing the modules into three levels (beginner, intermediate, and advanced). This meant that the reference pathway for all the links needed to be updated in each module page, since they were now in a folder (repository) one level above where the pages now resided. The wording of the questions and the hint strings provided to students was changed for the beginner and advanced levels so that they were appropriately geared to the desired reading levels. Sentences were shortened and word choice was simplified in the beginner versions of the modules, and hint strings were removed all together in the advanced modules. In addition to the change in the introductory reading passage that introduces the important vocabulary, these changes serve as the differentiation that was aimed for by this division into three tiers.

The last step in this process was to deliver the website to a server such that it could be accessed by anyone, anywhere. The domain www.6thgradescienceexploration.com was adopted, as it encompassed what the website can deliver to classrooms everywhere: the ability to use science to engage with problems. As the files all migrated from the git repository, which is a place to store shared code, the website was able to be hosted online. Once the live website was opened however, there were two problems. The first was that when opening the website, the landing page was an index of all of the pages instead of a home page. The second was that once

in the website, many pages and images were not loading. In order to get the pages to work properly, it was necessary to go back through and check the casing and spacing of each of the files (images and pages) in the repository, as there had been inconsistencies with referencing in terms of capitalization and several images had spaces in their names which could not be run through the hosting service. In the end of this term, between this project and other work, the decision was made not to include the 'emailing-to-teachers' feature, as it would have required an integration of the ability for students and teachers to login to the website, making note that there are supplementary worksheets for teachers to use in conjunction with the website. Ultimately, there is a fully functioning website that accomplishes the goals that had been originally set nearly two years ago.

Results:

The results gathered thus far have come from the responses received at the Copenhaver conference. Teachers were able to speak about their feelings toward the original layout of module 1, and what they wanted to see out of the rest of the website. Many of the teachers stressed the want for content that could be used with their struggling students, specifically their ELL students. It was also made clear that these teachers wanted content they could grade. Many were excited about this new way to introduce technology into their classrooms, but also wanted to make sure that it was going to be something that their students could connect to, regardless of that student's background. There was a split in opinion on how much mathematics should be integrated into the modules and website as a whole. The use of pictures was highly recommended, especially for the students below grade level in reading. The concept for the modules was generally well received.

Discussion:

The website is comprised of a page of six modules for students and a page of resources specifically for teachers. It is designed such that upon completion of six modules, students will have engaged with each of the sixth-grade science SOLs as well as several of the sixth grade math SOLs. Further, students will have had to use critical thinking and reading comprehension skills in order to be able to complete each module. For teachers, the provided resources page describes what they should expect to encounter on each page of each module along with some solutions. Additionally, there are supplementary worksheets for students to work on mathematics and reading comprehension. In combination with several free-response questions provided on the website, this would give teachers the ability to grade the work students do using each module, as this was also something in which the teachers present at the Copenhagen conference last June expressed interest.

The six modules are “River System Threats and Mitigations,” “Energy Transformations,” “Water and Its Functions,” “Solar Systems,” “Atmospheric Chemistry,” and “Keystone Species.” None of these fit directly with the stated Virginia 6th grade science SOLs, but the incorporation of each is evident when progressing through each module, and each are expressly stated in the ‘For Teachers’ page. As previously stated, each of the modules is comprised of several kinds of questions including drag-and-drop, click-interactions, slider-interactions, free-response, and vocabulary. While each of the modules does not include every kind of question, the modules are set up such that the style of questions is reasonably balanced. The goal is that having a range of question-type not only keeps students engaged but would require them to think differently for each question as well.

The concept of differentiation is central to the website. Differentiation is "a systematic approach to planning curriculum and instruction for academically diverse learners. It is a way of thinking about the classroom with the dual goals of honoring each student's learning needs and maximizing each student's learning capacity" (Tomlinson, Strickland, 2005, 6). This practice of differentiation is a valuable one, especially as classrooms become more diverse. Doubet and Hockett (2015) note that, "differentiation articulates how the classroom teacher makes important curricular goals accessible to all learners within the same classroom" (p. 2). By having the same science content delivered in three different reading levels and varying degrees of scaffolded support, the website meets the needs of a wide range of students in the modern classroom.

In order to better accommodate students, the website has three different levels for each module: a beginner, intermediate, and advanced. This allows for some differentiation for students at different ability levels. The beginner level is geared toward English Language Learners (ELL) and students who are below grade level in their reading and math skills. With this set of modules sentences are short and clear, and features vocabulary that is more commonly used at elementary reading levels. This is true for the introductory reading at the beginning of each module as well as the questions and hint strings within each page of the modules.

The intermediate level takes a step up in reading level for all of these sections and is aimed at the students who are on grade level in sixth grade, as dictated by the state of Virginia (Virginia Standards of Learning). Again, this is seen in the introductory page and within the question wording and hints. The advanced level modules have a higher vocabulary content, and contain fewer hints throughout the program, none of which are provided during the reading comprehension sections.

That said, the science content is the same for all three levels, as all sixth graders are expected to learn the same content in their science courses. As such, the website not only delivers on the overall content required for the sixth-grade science curriculum as dictated by the state of Virginia, but that content is delivered in a manner approachable to all 6th grade students.

In addition to the main modules, writing and mathematics extensions that build on the concepts are included within each module. These extensions can accompany each module and are also differentiated by ability level. The writing component features a beginner, intermediate, and advanced level, consistent in each of the modules. However, the math supplement only has two levels: introductory and advanced. The beginner writing pages have scaffolding in the form of sentence starters. They also feature a word bank to help nudge the students toward using the correct vocabulary for each question. Scaffolding is a strategy often used to provide needed support to students (Robb, 2003). The intermediate level loses these sentence starters but keeps the word bank to still provide students with some helpful hints in where their answer should be headed. At the advanced level, the students are simply given the question prompt without any additional guidance in how they should go about answering the question. The beginner level math worksheets break down each of the multistep problems into their single step components, but the advanced worksheet does not. The questions themselves stay the same.

The mathematics worksheets, which tie into the ideas of each module, were included to highlight the integration of science and math. Obviously, at the upper levels of science and mathematics, the two are inseparable; however, in earlier curricula for each subject, a hard distinction is drawn between the two. The addition of a supplementary mathematics worksheet allows students to make connections between science and math at an early point in their science

education. Further, the integration of real-world problems into the mathematics worksheet allows the students to answer the question, “How is this going to help me in life?”

Beyond differentiation, the modules are focused on real world problem solving. This is an aspect of science education that literature research suggested was lacking, particularly at the beginning levels. The website was planned out with the idea that students would be faced with real world problems instead of prescribed textbook-style problems. At its core, this approach was designed to eliminate the need for rote memorization of information (as is the tradition in introductory science courses). Instead, the use of real-world problems within the website challenges students to take the information with which they are presented and apply it, more than just repeat that information back in a different way. There were, however, some difficulties in the implementation of this style.

The development of the website itself forced many difficult decisions to be made in terms of the implementation of a true problem-based learning tool. HTML was first used to develop the website as it is the standard for web development, allowing for integration of text and images onto a webpage. To complement the HTML, CSS was added in order to allow for the addition of colors and properties such as sizing and font for the things on a webpage. Learning and incorporating those languages together took several months, providing motivation to seek out an easier option for the development of the rest of the website. In order to make the module interactable, JavaScript was used as it is the simplest language to convert images or text from being static to being dynamic.

Around the same time, teachers from the Copenhaver Institute suggested the addition of vocabulary pages for each of the modules. Feedback from teachers at the Copenhaver Institute also suggested that a purely problem-based module set would not be feasible since they would

want the ability to grade it within the module, meaning the module would need to be able to check a complex answer to a free response question. In order to do that, the free response question would have to be coded to recognize keywords in responses, but even then, it could not "know" if those words were used correctly. As such, the decision to switch from open-ended problems to simpler examples was made. Having consistency in question type across all of the modules inspired the creation of template pages to make the rest of the development easier.

In order to make a template, PHP was used since it can easily accommodate a template format. Although it is traditionally regarded as a less user-friendly coding language, it made the development of the website itself much easier after the template was created. The simplicity of the template could potentially allow for teachers to customize pages to their individual classes if they so desired. After the addition of PHP, the last coding task that was completed was the implementation of more complex animations. In order to accomplish that, jCanvas was used to insert a dynamic image into the page which can be interacted with. The main motivator for adding the animations was to provide students with another distinct type of page to keep them from getting bored as they work through the module.

The goal for this website is that it can be used within a classroom to provide a teacher with more flexibility to split their students into small groups and give more specific instruction to those students who need it most, or to be used as a starting point for teachers who may not have a strong background in the sciences. Another key use of this website is for content review, especially since, within Virginia, the SOL exam in eighth grade is covering all the content from sixth, seventh, and eighth grade science. The website could be used to provide a quick overview of primary concepts from sixth grade that would be useful leading up to this kind of cumulative standardized test. It could also be implemented in a language arts room that wants to have more

interdisciplinary work, or within a STEM based school system, since we do have several components on reading comprehension and writing. This wide range of applications was purposeful to provide teachers with a tool that has the flexibility needed to be applied in whatever ways an individual classroom may need.

Conclusion:

Since the completion of the website, the next phase of the project is implementation in an actual classroom. That would provide data which could be used to improve the individual modules so that they would be more helpful and more likely to be used by students. The Harrisonburg City School system has expressed interest in utilizing the website to help their eighth-grade students review the sixth-grade science material before their SOL testing in May of 2019. Additionally, a Roanoke College alumna has expressed interest in using the modules in a STEM middle school to help the language arts teachers give writing prompts based in STEM, even though that was not originally intended as one of the uses for the website. This demonstrates that the website is only limited in its use by a teacher's imagination. Further, it supports the willingness and enthusiasm of teachers to try new teaching techniques in order to help deliver information to their students. As this and other future data is reported, the website will continue to change to better fit the needs of students and teachers alike.

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