3D Printing and Reading Maps

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**Problem Statement:**

Reading maps is a skill that can take a considerable amount of time and effort to master. It’s a skill that generally comes with practice, however, it’s extremely beneficial to learn at an early age. Similar to other subjects such as science and math, geography is a skill that is used to gain additional skills and knowledge about the world. The earlier this skill can be mastered, the sooner it can be used to gain additional geographic knowledge.

One major problem in schools today is students are having a difficult time visualizing and reading maps, hindering their growth in additional geographic knowledge. These maps include regular 2D maps (where the cities are labeled and borders are drawn in between states and countries) and 3D elevation maps (maps showing hills, mountains, valleys, rivers, and different elevation changes). According to Ishikawa (2005), this problem is rooted [in] the student’s development of spatial thinking. Spatial thinking is a type of understanding that consists in many different applications. However, in the context of geographical understanding, Ishikawa (2005) describes spatial thinking as “recognizing, observing, recording, describing, classifying, remembering, and communicating with two or three-dimensional shapes, structures, orientations, and positions of objects, properties, or processes (Ishikawa, 184-186).” Basically gaining the ability to mentally visualize different shapes, volumes, and patterns in both two and three dimensions. Additionally, Bednarz (2006) describes spatial thinking as, “The knowledge, skills, and habits of mind to use spatial concepts, maps and graphs, and processes of reasoning in order to organize, visualize, and solve problems” (Bednarz, 402-403). When combining these definitions, it can be determined that spatial thinking (in the context of geography) is a type of thinking that allows for students to see different geographic landforms, shapes, and patterns in
2D and then visualize them in 3D where this visual thinking can be used to solve problems. However, it is very difficult for students to visualize landforms in 3D from a 2D map when they have never seen a map’s 2D representation in 3D.

Our solution to this problem is to use 3D printing technology to bring maps to life by printing different landforms located around the United States. This will allow students to create, see, and touch physical maps, equipping them with a 3D benchmark to improve their spatial understanding. The 3D technology will allow them to gain an additional perspective on elevation changes, landmarks, borders, and additional elements that can be seen on maps which will increase their ability to visualize maps. The purpose of this project is to get upper elementary students the skills to read maps and increase their spatial thinking skills. Very broadly our project will allow students the ability to learn about landforms, create a landform in CAD, watch their landform be brought to life in a 3D printer, and then present their findings to the class. This project allows students to use CAD software to create their landforms but allows them the ability to merge technology and art, to make a physical representation of a landform.

**Literature Review:**

Learning to read a map is an essential skill that is developed during a child’s early development. It requires regular practice and an effective teaching method. According to Edelson (2014), a 2010 National Assessment of Geography revealed that only 21 percent of fourth graders were performing at the expected level. The root cause of children’s inability to understand a map is due to their development in spatial thinking. Spatial thinking is the foundation of map reading and interpretation. Spatial thinking facilitates problem-solving
through the use of maps and processes of reasoning (Bednarz, 2006). According to Bednarz (2006), the reason that spatial thinking is so critical is due to the development of recent technologies that require critical thinking and spatial awareness. Consider GPS systems that require travelers to understand their location relative to the map and guide their way to the desired destination. The development of Google Earth has introduced the ability to view streets in a 3D view at various angles. Organizations and governments utilize maps to display information regarding taxes or neighborhood cleanup decisions. Also, animated maps are more frequent. They can show election results across a region, forecasted weather, or the effect of certain natural disasters on a region such as a flood. Therefore, it is critical that children have a strong background in spatial thinking so that they can understand the impact of a map in emerging technologies (Bednarz, 2006).

According to Ishikawa (2005), “spatial thinking can be described in five ways: (1) It is the ability to recognize, observe, classify and communicate 2D or 3D shapes and positions of objects, (2) The mental manipulation of those shapes by rotation, translation, deformation or removal, (3) The interpretation about why the object had a particular shape, structure, and orientation, (4) Predicting the consequences and implications of the shapes, orientations, and positions, (5) Use spatial thinking as a tool to think about distribution process across a dimension other than length-space (Ishikawa, 184-186). The ability to perform these five tasks positively impact users spatial awareness. According to a trial on the effectiveness of training spatial thinking done by Ishikawa, participants that were given training on the tasks improved significantly more than those that were not trained on spatial tasks. In the context of
understanding a map through the use of hands-on tools that simulate spatial thinking, students that are taught effectively by educators can improve in their understanding of reading a map.

An additional reason that children struggle to interpret maps is attributed to how educators are teaching the material. According to Bednarz (2006), teaching about maps only provides students with the basic skills and understanding to read and interpret maps. On the other hand, teaching with maps requires the educator to use actual examples of maps to help students learn concepts and relationships. Learning through maps enables students to think spatially through various reasoning and problem-solving contexts. Bednarz suggests that children possess the spatial skills required to understand maps. Additionally, children have the ability to understand symbols and patterns represented by color and shading. Therefore, children can naturally interpret a map without formal instruction (Bednarz, 2006).

To overcome the difficulty in understanding maps, children should utilize spatial awareness and the ability to understand symbols to improve their map reading skills. Edelson (2014) recommends that children be presented with challenging tasks that demand them to learn new skills, but at the same time, the new skills should not overwhelm them. Three solutions that were identified in a survey conducted by the Texas Alliance for Geographic Education in Bednarz (2006) article were “(1) employing hands-on activities, (2) repeating lessons periodically, and (3) making the content relevant” (Bednarz, 399). Using the hands-on approach provides a way for students to critically learn concepts and relationships by learning with maps. A recommendation by the National Geography Standards is that children in the fourth grade make maps. They state that a student should be able to read a story and create a map to describe
it. An additional recommendation by the National Geography Standards was that students should be able to produce maps with new technologies (Bednarz, 2006).

A solution that presents a new challenge to children and invites new lessons to be learned through hands-on activities is 3D printing. The concept of using 3D printing to develop spatial thinking has been used in many different applications because 3D printing provides a unique experience to manipulate objects in the elements of spatial cognition. These elements include spatial visualization, spatial orientation, spatial relation, mental rotation, and visual memory (Huang, 2017). In a study conducted by Huang (2017), solid models were able to enhance learners’ spatial ability.

The use of 3D printing can teach elementary students many different skills. From an article by Cook, Bush, and Cox (2015), a study was performed on how elementary students incorporate 3D printing in the classroom to solve a problem. The teacher incorporated the use of STEAM and 3D printing into a six week period, with each week focusing on different skills students will learn. Week one focused on building students’ empathy. Week two focused on guided research, and during week three, students had to create a blueprint on tinkercad. In the fourth week, students were building their prototype out of 3D printed materials. Finally, the students finalized their designs and agreed on one design to be printed (Cook, Bush, and Cox). With the culmination of skills gained from using a 3D printer, students learned to problem solve, work together, research, use interactive software, work with their community, and finally see their finished product be printed in a 3D printer.
**Recommended Solution:**

According to Huang (2017), an effective method to improve children’s spatial thinking (in regards to interpreting maps) is to use a 3D printer to provide students with a 3D landform that they can use to understand 2D representations of those landforms. This can be accomplished by incorporating a lesson plan for a fourth-grade teacher to use during a geography unit, focusing more specifically on teaching students how to read maps. The lesson plan follows both Michigan State Standards (You are here MDE, 2019) and Common Core National Standards (Read the standards, 2019) from the areas of social studies and art. Students will look at both maps in 2D and 3D relations and create their own landforms. The lesson begins with the students deciding if they want to work with a partner or independently. Then, the individual or group decides which landform they would like to create on the website: Terrain2STL. This website allows the student to print any landform in the world! The students can obtain a landform boundary by pressing the button “center to view” and changing the size of the box to change the landform boundary. The size of the landform that can be created from this site ranges from the size of Grand Rapids to the size of half the United States.

Once the students determine the boundaries of their landforms, the 3D printed file (.STL) is created by selecting the “generate” button on the website followed by the “download” button to obtain the .STL file. Once obtained, the file is opened with a 3D printer and printed. As the landform is being printed, expect time for the students to watch the printer and be amazing as they see something 2D (from a computer screen) comes to life in 3D. While the students are waiting for their landforms to finish printing, they will work on researching their landforms to prepare for a presentation. This is because a day or two after, the students will present their
landforms to the class by sharing historical facts about the landform and showing the 3D model to the class. An example of a 3D printed landform can be seen in Figure 1.

![Figure 1: 3D printed landform of the United States.](image)

As seen in Figure 1, a 3D printed version of the United States was made where it shows distinct elevation differences where the Appalachian and Rocky mountains are present. Additionally, the 3D printed model shows just how flat and elevation-less the United States is in the center. Allowing students to really see and understand how vast and wide the grasslands are. Although this model wasn’t printed from Terrain2STL, it was printed from Thingiverse where a topographical map of the United States was converted to a .STL file and printed. This website also has the topographical .STL files for other landforms such as alaska, hawaii, grand canyon, and other countries around the world. Showing that Terrain2STL isn’t the only capable website to perform this lesson plan.
With creating a lesson plan for the solution, there are always benefits and drawbacks because each student learns differently. Some drawbacks to this solution consist of the amount of time this lesson takes, and veteran teachers may not know how to use the software to print the landforms. This lesson takes about four days, in which the students are solely focusing on one landform instead of learning about many at one time. The other drawback to this solution is, older veteran teachers may not know how to use 3D printers and other technologies to implement this technology into the classroom. One way to improve this drawback is to implement Professional Development (PD) to help veteran teachers learn how to use new technology in the classroom. According to Scott and Mouza (2007), the finding suggest that “effective professional development needs to help teachers: (a) enhance their understanding of their subject matter with respect to technology; (b) increase their experience using technology (e.g., blogs, wikis) as learners; (c) improve their experience using technology in an instructional setting; (d) assume more leadership responsibilities within and outside their school boundaries; and (e) establish a sense of community that can support classroom implementation of technology” (Scott and Mouza, 263). From PD, veteran teachers will learn how to use a variety of technologies, depending on what they want to incorporate into the classroom. Some ways PD can be effective is by teaching these teacher the basics on how to use it and how it can help improve their teaching in the classroom. Then at the PD teachers can test out the technology, to get one-on-one instructions, to make sure they know how to use it and to make sure they feel comfortable using to teach. To conclude these teacher will know how to use a variety of technologies and they will know how to implement it into the classroom.
While there are some drawbacks to this solution, the number of benefits are greater. Some of the benefits include combining the use of art and technology, practicing their research skills, and improves student spatial thinking. According to Hyunkyung (2017), “Researchers found that student-centered, technology-integrated learning environments help to produce students who are better able to think critically, solve problems, collaborate with others, and engage deeply in the learning process” (Hyunkyung, 37). Involving art and technology together fully engages students with wanting to learn about the content. In this lesson, students are also practicing their research skills by looking up key details of the landforms and presenting them to the class. Another benefit is the cost of a 3D printer has significantly decreased in the past five years. A 3D printer that can be sufficiently used in a classroom setting can cost as low as $150 to $300. With this low price, the size of 3D printers has also dropped to the point where they can be set up on a countertop in the classroom to be used regularly. Also, they are very easy to learn and assemble. Each printer comes with a manual (how to build and how to use manuals) and has a large support base online that can help with any printer setup or operating needs. The final benefit of this solution is it aids students in their understanding of maps with a hands-on approach that simulates spatial thinking. If students are taught effectively through this approach, their understanding of reading maps can increase greatly.

However, this solution will look differently in the eyes of the audience. From the teacher’s perspective, he/she created the lesson according to standards and providing a way to bring new technology into the classroom. This can look different from teacher to teacher because every teacher has a different personality and teaches differently. From the perspective of the parents, they’ll get a handout of what the students are doing in class. Therefore, they will be
informed on what their student is doing in class and may decide to help students do some research at home, but it would not be a requirement. From the perspective of the student, they are learning about landforms, reading 2D and 3D maps, and using 3D printers to create a landform. This will be perceived differently in every student because some students will enjoy creating and using 3D printers, while other students may think the opposite. From the perspectives of the parents and teachers, they ultimately want what is best for the student and are willing to help when and wherever it is needed.

The solution because students are having a difficult time reading and understanding 2D maps. Based on the literature, the root cause of this problem is due to the way students learn and understand spatial thinking. Research suggests that 3D printing can improve a student’s spatial thinking. 3D printing allows students to learn through making. It provides a hands-on physical model that students can see and feel. This interaction allows children to learn about geographical features and symbols with maps rather than just about maps (Bednarz, 2006). Using hands-on models provides students with the ability to physical rotate, orient, and visualize models. Through this hands-on approach, students naturally go through the five components of spatial thinking, and overtime, spatial ability will be improved (Huang, 2017). Therefore, utilizing a 3D printer is an effective solution to help students read and interpret maps.

**Evaluation:**

The effectiveness of the lesson will be evaluated in the form of a written test. Students will be required to locate different landforms on the 3D printed object. Each map will be of a different geographical location or ocean, and students will be able to choose from the various selections. If the students choose the United States of America, for example, they could be asked
to pinpoint the highest and lowest points in the country. There would be extra credit questions, and they would range from easy to challenging. The entire test would be 20 points with each question ranging from 1 to 5 points. If the students chose an ocean, for example, they would be tested on where the trenches would roughly be located, and the different layers of the ocean, like the Twilight Layer. The format of the test will be a mix of multiple choice and short answer. An example multiple choice question will ask the students to ‘determine which mountain range is the highest out of a given set of mountain ranges.’

The project will be deemed a success if a high percentage of the students pass with at least a B on the final test. Depending on if there are a high number of students in the class, the average of every student will be taken into consideration instead. The statistics will be used to determine if the test scores improved from the previous year and from the pre-test that will be given at the beginning of the year. The students will be tested on memorization, spatial understanding, and how well they can identify different elevations. There will be a “midterm” that will let the students divide into pairs or small groups and work together to solve problems of elevations on the 3D object. It will help the students establish an understanding of how the landmarks look on a physical map.
References:


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