FEATURES

Architecture

A Nexus of Creativity, Math, and Spatial Ability

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Abstract: The United States is dependent on innovations in science, technology, engineering, and math (STEM) fields for the growth of its economy and improvements to quality of life, but too few students are prepared for them. To help meet the challenges in filling the STEM pipeline, teachers of gifted elementary students can nurture important talents, including mathematics achievement, creativity, and spatial ability, through problem-based architectural projects. The importance of developing each of these talents for STEM success is described and related to architecture. Four projects are offered in architecture and various architectural sub-disciplines that are sufficiently challenging for gifted elementary students, including example Common Core State Standards in mathematics that can be incorporated. The usefulness of problem-based learning is described, and problem statements are offered that can be easily revised and extended to meet unique classroom needs. A framework is provided for teachers to create their own architectural projects.

Keywords: architecture, creativity, mathematics, spatial-visual

> "To help meet the challenges in filling the STEM pipeline, teachers of gifted elementary students can nurture important talents through problem-based architectural projects."

Innovations in science, technology, engineering, and math (STEM) have driven the U.S. economy since World War II and provided tremendous increases in quality of life (National Science Board, 2010). However, too few U.S. students are entering STEM fields to fill the increasing needs (Langdon, McKittrick, Beede, Khan, & Doms, 2011). Declining creativity, elementary school teachers who are generally poorly prepared to teach math, and a lack of opportunity for spatial talent development are all potential threats to continued STEM innovation (Kim, 2011; National Science Board, 2014; Wai, Lubinski, & Benbow, 2009). Gifted students, those with the greatest potential to become STEM innovators, too rarely receive instruction appropriate to their abilities and thus make among the lowest achievement gains in school from year to year (Colangelo, Assouline, & Gross, 2004; Rogers, 2007; Sanders & Horn, 1998). These problems, coupled with classroom time constraints under the demands for standardized test preparation, appear to present a conundrum for classroom teachers (Evans, 2013; Joravsky, 2012; Strauss, 2012).

Architecture can be considered a nexus of creativity, mathematics, and spatial ability. From the Egyptian pyramids and the Duomo of Florence to Frank Lloyd Wright's Falling Water and Shanghai's Mobius Strip Temple, great examples of architecture throughout history have been born of these capacities. Architectural activities are ideal for challenging gifted students in each of these areas. They are filled with possibility for real-world problem-solving and presentation to critical audiences. Nurturing students' creativity, math achievement, and spatial ability are each important for increasing overall readiness for STEM fields. In this article, we offer several problem-based architectural projects that involve spatial challenge and creative opportunities, and relate to Common Core State Standards (CCSS) in mathematics.

Creativity, Spatial Ability, and Mathematics

Before introducing the architectural projects, a background in the relationship of creativity and spatial ability to mathematics may be helpful. Creativity is the ability to generate something new and useful. In what has become

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known as the Creativity Crisis, Kim's (2011) landmark study of more than 200,000 students' creativity test scores from the late 1960s to 2008 found that creativity has been in decline among U.S. youth over the past two decades. In particular, Kim found a 37% decrease in the ability of students to elaborate on their ideas from 1984-2008. Although the causes are unknown, Kim and Coxon (2013) explored several likely culprits including the minimum competency standards movement. In particular, a hyper-focus on multiple choice test scores has resulted in increased classroom time for rote forms of learning and less time spent on extended activities, including those allowing for creative development. Creative projects take more time to ultimately emerge with an elaborate product and may be seen as taking time away from test preparation in the current school climate. However, we argue that engaging, extended projects in architecture allow teachers to meet mathematics standards while also allowing for creative talent development. Existing research with other building activities such as student use of LEGO have demonstrated increases in creativity (Coxon, 2012a).

Architectural projects, when tied to CCSS in math, may increase math achievement test scores. The architectural projects we offer below can be considered problem-based learning (PBL). In PBL, students are given a real-world problem and then must design and test potential solutions to solve the problem. PBL enhances retention needed for standardized tests (Dochy, Mein, Van Den Bossche, & Gijbels, 2003; Mergendoller, Maxwell, & Bellisimo, 2006). A meta-analysis of PBL focused on studies in medical education found a meaningful effect size on understanding concepts and principles (d = .795; Gijbels, Dochy, Van den Bossche, & Segers, 2005). The authors concluded that students' path toward expertise is accelerated by PBL interventions. Intervention studies involving PBL units in K-12 schools have also demonstrated gains in student learning. VanTassel-Baska and Bass (1998) and VanTassel-Baska, Avery, Hughes, and Little (2000) examined science units utilizing PBL and found significant gains in student learning. This is time well-spent, and not only for improving test scores. As with PBL generally, the open-ended nature of architectural projects also offers possibilities for creative talent development. While creativity has been in decline, it is improvable through challenging, open-ended yet purposeful building activities (Coxon, 2012a, 2013a). Such activities may increase scores on measures of spatial ability as well (Coxon, 2012b).

Spatial ability is often thought to be merely a facet of math ability, but they are very different forms of thinking. Spatial ability is "the ability to generate, retain, retrieve, and transform well-structured visual images" (Lohman, 1993, p. 3). Although some subjects taught in math courses are spatial, especially geometry, this is not generally the case (Coxon, 2013b). Spatial ability, also referred to as visual-spatial ability, involves thinking in images, whereas math generally involves thinking in symbols (Coxon, 2013b). In fact, math ability is more highly correlated with verbal ability than with spatial ability (Wai et al., 2009). Einstein, Faraday, Tesla, Galton, and many other innovators have offered that verbal thinking played little role in their creative thinking; they instead relied upon visualization (Lohman, 1993). High spatial ability is predictive of success in STEM fields, including innovations (Flanagan, 1979; Humphreys, Lubinski, & Yao, 1993; Super & Bachrach, 1957; Wai et al., 2009; Webb, Lubinski, & Benbow, 2007). As with geometry, math and spatial talents can be developed simultaneously with architecture. Having both high math and spatial abilities is beneficial in STEM fields (Wai et al., 2009). When coupled with high math and spatial abilities, well-developed creativity is ideal for STEM innovation.

The CCSS in math can be found at http://www.corestandards.org/Math/ and were developed to encourage students to solve real-world problems (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010). The CCSS in math are also meant to be clustered, not taught in isolation. All of the projects lend themselves to multiple standards. Example standards suitable to cluster for each project from one grade level are listed after each project, but many more are applicable at any elementary grade level, and it is beyond the scope of this article to list all of those that may be clustered. Teachers should cluster the standards as appropriate for their grade level. This article uses the standard abbreviations of the CCSS in math. For example, K.G.B.5 means kindergarten-level, geometry, B.5 standard. This allows teachers to reference the standards quickly.

Architecture and Gifted Students

Architecture is a broader field than many may think. Architecture involves designing buildings along with a variety of tangential disciplines, which include industrial design, interior design, and landscape architecture. Incorporating the study of architecture into the classroom involves possibilities for creativity, spatial demands, and student engagement with mathematics concepts such as scale, proportion, and pattern.

Gifted students are precocious, complex, and intense in comparison with other students their age (VanTassel-Baska, 2005). Gifted students should receive more challenging activities than their age-peers to continue to develop their talents, including those in creative, mathematical, and spatial domains (Rogers, 2007). Unlike a typical math worksheet or multiple choice test, the activities presented here have no ceiling on student achievement (Krauss & Boss, 2013; Mullis, Martin, & Foy, 2008). Gifted students usually prefer more complex activities than their age-peers (Davis, Rimm, & Siegle, 2010). Due to their open-ended nature coupled with problem solving, the architectural projects presented here offer greater potential for complexity than typical, close-ended mathematics activities. Gifted students are also often more intense than their age-peers (Cross, 2011). The projects presented here, when given sufficient time, allow for gifted students to work intensely with the materials to create a final product. Likewise, PBL in general is ideally suited for these traits of gifted students in that it provides opportunities for advanced work, is potentially very complex, and allows for student ownership and intense, in-depth product development (VanTassel-Baska et al., 2000).

An architectural program for young students in Britain, known as the t-sa (Toh Shimazaki Architecture) forum mini workshops, indicates that simplifying complex problems for young students is the wrong approach (Bossi, 2013). Program leaders report that the participating students are often more creative in their use of materials than university students due to a lack of preconceptions about architectural disciplines and greater flexible thinking with materials. This aligns with longitudinal studies suggesting that divergent thinking levels are highest in youth (Camp, 1994; Land & Jaman, 1992; McCrae, Arenberg, & Costa, 1987). This freedom from limitations serves as the departure for the projects described here. Consider the following framework in developing classroom architectural projects, with examples provided to generate ideas.

Architectural Project Framework

It is important to note that despite its heavy reliance on mathematics, the discipline of architecture relies substantially on creativity, too. In the interest of simplifying lesson planning, the following list of project ingredients may be utilized by teachers as a conceptual framework in developing their own classroom projects. When developing architectural assignments, considering a mixture of project scales, disciplines, and cultural factors adds challenge and complexity while increasing opportunities for creativity, spatial challenge, and math standards connections. There are nearly unlimited possibilities for embedding the CCSS within the projects. Consider the standards offered merely as examples or thought-starters; many others may be applied and clustered. With gifted learners in mind, higher-order questions are offered with foci on synthesis and evaluation. The projects are all suitable for elementary students in grades K-6, with teacher differentiation based on student needs and abilities. These example projects are offered at a high level based on our experience that it is easier for teachers to simplify projects for younger students and those that are less able than to increase complexity and challenge for the most capable.

The following list of project ingredients is intended to be *mixed and matched* to formulate architectural projects suitable for gifted elementary students. Specific examples for how this list of ingredients is intended to be used in developing lesson plans are presented in the following four example classroom projects.

Project Ingredient Descriptions

Scale of Project is a subjective classification that refers to the size of the hypothetical projects relative to one another. It may be useful for teachers to begin developing original classroom lessons by first considering the size or scale of an intended end-product. It is important to note that scale is relevant in terms of level of detail the students will consider for their design projects. For example, if the teacher aims for students to complete high levels of design detail, a smaller scaled project is appropriate (see Project 3 below). If the teacher is interested in students developing broader, big picture ideas, then consideration for a larger scaled project is applicable (see Project 1 below).

The terms found in the category *Architectural Discipline* refer to various facets of architectural practice. Building design, interior design, and landscape architecture describe the design of buildings, interior spaces, and outdoor areas, respectively. Industrial design encompasses the creation of everyday objects.

Under *Social or Cultural Context*, environmental sustainability prioritizes consideration for natural conservation and recycled products, whereas universal design approaches building design as inclusive for all people, including individuals with physical disabilities. Current events may refer to popular culture items from which teachers may draw inspiration when writing projects (e.g., a teacher may consider a fictitious sport, like *Harry Potter's* Quidditch for example, and ask students to design an arena around it), and immediate surroundings refer to

Project ingredients		
Scale of project	***Architectural discipline***	***Social or cultural context***
Small	Building design	Environmental sustainability
Medium	Interior design	Universal design
Large	Landscape architecture	Current events
	Industrial design	Immediate surroundings

environments for which students can gain direct access (e.g., their school, house, or community playground).

Materials and Tools

Teachers may use any classroom materials they have on hand or can easily acquire for the projects below. For the three-dimensional modeling projects, an appropriate list of materials may include cardboard, cardstock, note cards, newspaper, colored paper, craft sticks, fabric, clay, plastic or bubble wrap, string, wire, glue, and tape. Model-making tools may include a variety of rulers, protractors, tape measures, scissors, cutting mats, and hole-punches. For drawing projects, graph paper, large sheets of butcher paper, and a variety of drawing tools are appropriate. These materials and tools are intended as thought-starters only, and teachers and students are encouraged to consider using any materials they have available.

Evaluation Criteria

Finally, it may be useful for teachers and students together to develop and define evaluative criteria that will be utilized in assessing final design projects. In architectural practice, projects are basically evaluated on two broad principles: problem solving and aesthetics. Problem solving refers to an architectural project's ability to achieve the goals it set forth to meet. For example, is the space generous enough for the intended activities to take place? Are the proposed materials of the project appropriate for the design's function? The latter of these criteria, aesthetics, requires more subjective reflection. Discussion points surrounding the aesthetics of a project may include the use of a harmonious color palette, the rhythmic inclusion of line and form, and the creativity of concept and space-making. Neatness of craft and presentation are likewise appropriate to discuss when evaluating the aesthetics of student projects.

Project 1: Design an Outdoor Classroom

Project ingredients

Scale of project: Medium
Architectural discipline: Landscape architecture
Social or cultural context: Immediate surroundings

Materials

Cardboard, colored paper, basswood sticks, and clay represent just a few possibilities.

Problem

While the outdoors contains a wealth of learning opportunity, it can be hard to do schoolwork outside because of the weather, a lack of writing surfaces and seats, and distractions to students.

Process

Step 1. Outdoor classroom spaces provide rich opportunities for learning in a natural setting with natural materials. Begin by asking students to consider what they would like to have in an outdoor classroom at their school. Students may record their ideas through writing, drawing, or making small models from cardboard, construction paper, or craft sticks. This first step focuses little on accurate representation and more on creative brain storming—encourage students to think creatively, and document any and all ideas that come to mind. Potential questions for student consideration may include the following:

What is necessary to include in an outdoor classroom space?
Answers may include: places for students to sit, tables upon which to work, shade
What amenities would enhance learning in the outdoor classroom space?
Answers may include: a picnic shelter, garden beds, a pond, a weather station
What optional components could be included as a wish list to enhance the quality of space for the outdoor classroom?
Answers may include: a fountain, flowers, benches, sculpture

Initially, student answers may include things commonly found on the playground. Remind them that the focus of an outdoor classroom is educational and would be new and different than what is already available at the school.

Step 2. Next, take students on a tour of the school grounds, and ask students to consider the proper site, or location, for the outdoor classroom. Discuss the pros and cons of each site, including the position of the sun and the presence or absence of shadows throughout the day. Discuss the importance of nearby landmarks (natural or man-made), and existing terrain, for example. Students may *approximate* the overall dimensions of each potential site by measuring the length of a single pace and then walking the perimeter of the outdoor area. Once back in the classroom, ask each student or team of students to select the ideal site for the outdoor classroom, based on their observations, and to draw the site plan on graph paper. Teachers will likely need to instruct the students on establishing the appropriate scale for the drawings on graph paper. Teachers may establish the guidelines that "the length of each square on graph paper is equivalent to five feet," for example.

Step 3. Ask students to design their ideal outdoor classroom, which includes the wish list from Step 1, and considers the site context from Step 2. Students can represent their projects by making drawings on graph paper utilizing the same scale established in Step 2. Students shall also represent their projects by making small models of their designs using any classroom materials the teacher may have on hand attached to a cardboard or other suitable base. It is important to again emphasize that design is subjective, and therefore there are no right or wrong answers in developing the projects.

Step 4. Finally, students may present their projects to the class, and teachers can lead a constructive design critique that discusses the differences between the various student projects and addresses the evaluative criteria established at the beginning of the project. Teachers may consider inviting outside guests to take part in the critique (e.g., the principal, other classes, families, or professionals who may have played a role in the development of the projects). Teachers shall reiterate that while no right or wrong answers exist, there are likely more and less suitable projects that the students present. Refer to the wish lists established in Step 1, and critique the projects based on whether or not these wish lists are suitably fulfilled.

Example related mathematics CCSS

A wealth of mathematics is built into this first project, easily connected with the CCSS across elementary grade levels, allowing teachers to make modifications suitable to the abilities of the students they teach. It is ideal for fourth grade students, and many standards can be clustered in this project. Measurement is easily incorporated, from early shape recognition and measuring perimeter to the more complex area of unusually shaped spaces (e.g., 4.MD.A.3 Apply the area and perimeter formulas for rectangles in real-world and mathematical problems. For example, find the width of a rectangular room given the area of the flooring and the length, by viewing the area formula as a multiplication equation with an unknown factor). Likewise, geometry is well-suited to this project (e.g., 4.G.A.1 Draw points, lines, line segments, rays, angles (right, acute, obtuse), and perpendicular and parallel lines. Identify these in two-dimensional figures). Finally, the large scale of this project lends itself to place values in the 10s and 100s (e.g., 4.NBT.A.1 Recognize that in a multi-digit whole number, a digit in one place represents 10 times what it represents in the place to its right. For example, recognize that 700 ÷ 70 = 10 by applying concepts of place value and division). Teachers will find it is easier to locate CCSS that can be incorporated into this project than those that do not.

Project 2: A Place for Reading

Project ingredients

Scale of project: Medium
Architectural discipline: Interior design
Social or cultural context: Immediate surroundings

Materials

This assignment is intended to be built at full-scale, and therefore materials that can be acquired in large sizes and quantities shall be considered for this project such as fabric, cardboard, and carpet squares.

Problem

Develop a place for leisurely reading that focuses on comfort and quietude.

Process

Step 1. Begin this project by following Steps 1 and 2 of Project 1, but this time for an interior space. Appropriate interior spaces for this project may include the students' classroom, an area within the school library, or another nook within the school that makes sense for its proximity to natural light. Following the steps above, ask small groups of students to document their wish lists for a Place for Reading, as well as any appropriate site features. Groups should create proposals for their ideal reading spaces in writing and drawing.

Step 2. Ask groups of students to build, at full scale, their idea of the perfect Place for Reading. Materials for this step can include cardboard, felt, fabric, paper, or any other material the school is capable of economically acquiring in abundance. Emphasize the importance of craftsmanship and accuracy as the students build their projects. Assist the students in carefully measuring pieces of material for the construction of their Places for Reading.

Step 3. Ask students to constructively evaluate each design for A Place for Reading. What is successful about the designs? What could be improved upon? What was their favorite part of constructing the spaces? What was the most challenging aspect of the project? Students should revise their designs based on this feedback.

Step 4. Invite another class to come and utilize the reading spaces and to provide feedback on them such as their comfort and freedom from distractions. Again, teachers can lead a classroom discussion that critiques the finished products based on the previously established evaluative criteria.

Example related mathematics CCSS

This project lends itself to identical standards as Project 1, but on a smaller scale.

Project 3: Build a Better Lever

Project ingredients

Scale of project: Small
Architectural discipline: Industrial design
Social or cultural context: Universal design

Materials

Students may propose low-tech solutions for this project, as well as mechanical and high-tech solutions (e.g., pressing a button, pulling a string attached to a pulley, or waving a hand over a sensor, real or imagined, to operate a door). For these reasons, appropriate materials may include clay, cardboard, cardstock, string, pulleys, springs, magnets, or even batteries, hobby motors, or LEGO robotics sets.

Problem

Everyone is different. Sometimes these differences make every day activities, such as opening doors, difficult or even impossible. Children, the elderly, and people with physical disabilities should all be considered in the facets of public spaces.

Process

Step 1. Universal design is a large and complex topic, but teachers may begin the discussion appropriately leveled and abstract. This project could also lead to further research into universal design by students for greater depth. Begin by discussing the importance of considering all populations when designing buildings for people. Include within the discussion principles of universal design that emphasize equitable, flexible, and intuitive use of building components with little physical effort required. It may be useful to take the students on a tour of the school building, and to point out specific building elements that directly respond to universal design. These building elements may include a bathroom faucet lever for people with limited use of their hands, a ramp for people in a wheelchair, and large-scale signage for the visually impaired, for example. Ask the students to consider the differences in how a small child, a tall adult, and a person with an injured hand may open a door or cabinet. Record the class feedback in a central location for students to reference throughout the development of their projects.

Step 2. Next, explain that this project will specifically focus on the design of a better lever, and assist students with researching what currently exists as options for door hardware. This research will likely include standard door knobs, pulls, and handles, and lead to finding examples of more sophisticated door hardware systems, including mechanical and digital options, motion sensors, and even mobile applications that control doors opening and closing. Internet research is appropriate for this step, but teachers may also lead students through the school and point out the variety of hardware found on doors nearby. Understanding existing door hardware systems may assist students once they begin designing their own solutions.

Step 3. Using graph paper or modeling supplies, ask students to design and build a better lever utilized in opening a door. Encourage students to consider ambitious, novel solutions. Some students may propose improvements to the existing standard lever, whereas others might propose solutions that incorporate technology not even yet invented. Given sufficient time, this project provides opportunities for students to develop perseverance as they make attempts that may be unsuccessful but have opportunities to try again, leading to success over time. Teachers may wish to document student prototype iterations over time and provide feedback using photographs.

Step 4. Ultimately, students should have the opportunity to present their ideas to an audience. It may even take the form of a competition, which is often highly motivating for gifted students (Coxon, 2009). To determine which design fits the broadest range of potential users, the teacher could invite guest judges into the classroom. This group may include community members, a special educator, or a local interior designer.

Example related mathematics CCSS

This project lends itself to geometric and measurement standards across grades. The project may include multiple forms of data collection and representation. For example, third-grade students could count the number of iterations a design took until success, the number of pieces used in each design, or the number of conditions a design accommodates and then represent these data to share as part of step 3 (e.g., 3.MD.B.4 Generate measurement data by measuring lengths using rulers marked with halves and fourths of an inch. Show the data by making a line plot, where the horizontal scale is marked off in appropriate units—whole numbers, halves, or quarters). This standard could be clustered with other third-grade standards, including the use of various quadrilaterals (e.g., 3.G.A.1 Understand that shapes in different categories may share attributes, and that the shared attributes can define a larger category). If students create scale models on graph paper before building, the project lends itself to measuring area on a small scale (e.g., 3.MD.C.6 Measure areas by counting unit squares such as square cm, square m, square in, square ft, and improvised units).

Project 4: Wayfinding Design and Installation

Project ingredients

Scale of project: Large

Architectural discipline: Interior design

Social or cultural context: Universal design and environmental sustainability

Materials

Cardboard, matte board, and poster board along with other materials that may be acquired in large amounts are appropriate for this assignment. Materials that are heavily textured or patterned, such as bubble wrap, sandpaper, or patterned paper, are also useful for this assignment. This exercise also provides an opportunity to explore environmental sustainability through the topics of recycled and green building materials.

Problem

Finding your way in an unfamiliar space, such as a new school, can be challenging. The challenge is increased greatly when navigating a new place is coupled with a limitation, such as visual or physical impairment.

Process

Step 1. Ask questions that draw upon students' prior knowledge of finding their way. Topics may include using landmarks, maps, global positioning systems, and signs as well as experiences such as travel, being lost, or navigating a large building. Introduce the concept of wayfinding, a trend that has emerged in interior design. Wayfinding, described as spatial problem solving, is the art and science of developing clear navigation between two points within a building (Beyer et al., 2002). Though wayfinding depends heavily on interior graphics and signage, successful wayfinding also incorporates changes in flooring, wall, or ceiling finishes; various sizes and types of artwork throughout a building; and various landmarks to serve as indicators for one's relative location within a building. Changes in materials and textures are especially helpful in assisting people with visual impairments navigate interior spaces. An example of how successful wayfinding may work would be to give the following directions to somebody searching for the restroom in a large office building, hospital, or school:

> Take this hallway until you reach the textured tile floor, then take a right. When you find the large statue of Winston Churchill, make a left, and the restrooms are just a few doors down clearly marked with a sign that includes braille.

While all of these projects can be considered PBL, this one lends itself especially well to it. Teachers may lead with a problem statement, such as solving navigational challenges that a new student or parent may encounter when visiting the school. Discuss the various challenges visitors may encounter when navigating throughout the building. One optional modification to this project would involve introducing the challenges a person may further face when navigating with a visual or physical impairment.

Step 2. Begin this step by asking the students to determine a few of the most difficult locations to find within the school building. Determine a hypothetical scenario that includes physical beginning and end points within your school building, such as a new student or visitor needing to find her way from the office to the library or computer lab.

Step 3. Once you have determined the physical path for this exercise, ask the students to sketch maps from start to finish. This step in particular requires students to think spatially. Ask students to draw this step from memory first, and to record any appropriate landmarks along the way. Asking students to begin by drawing the paths from memory will likely shed light on any remarkable points along the path, including already-existing pieces of artwork, changes in interior materials and textures, and important intersections along the path. After the students have drawn the routes from memory, ask them to walk the path with the maps they created. Were the maps entirely clear, accurate, and complete? Ask the students to record anything that may clarify the route, and add useful landmarks or building features they may have forgotten. Finally, instruct students to ask a classmate to follow the route utilizing each other's maps, and to make notes indicating points that need clarification. Are there points along the route where it is unclear if the visitor shall make a left or right? Are there moments along the path where the flooring and wall color become monotonous, and may be improved by incorporating variation in color or pattern? Are there various textures on the floor or wall, or tangible pieces of sculpture or art that may serve to assist people with visual impairment follow the same path? Is all necessary signage appropriately legible from a distance and considerate of visitors whose vision may be less than perfect?

Step 4. Ask the students to make drawings and models of design proposals that will improve a visitor's ability to find their way along the route. If using the optional modification of a new student with visual impairment, encourage the students to explore tactile solutions such as moments where visitors can physically feel the path along the floor with their feet or touch different textures along a wall. In other situations, solutions may include changes in wall color, changes in flooring pattern, or the addition of artwork on the wall. Solutions may also include adding signage, sculpture, or ceiling features at key changes in direction. Students may also be asked to prepare a budget using the Internet or a guest from a local hardware store. Once the students have developed their designs, ask the class to assess the proposals. Eventually, the class should select one proposal or a combination of several proposals that best solves the problem statement to potentially carry out at full scale.

Step 5. Have students propose the design to an appropriate panel of experts and school decision makers, such as the principal, custodian, and special educator. Finally, the teacher may assist the students with installing a portion or all of their design projects, at full scale, within the school. Students can make the signage and wall art out of craft paper or other textural materials. Students can use cardboard or poster board to add texture and color to the floor plane. Encourage students to build as much of their project as is feasible. Some pieces of the designs, such as ceiling features, may be difficult for students to build and install. Encourage the students to take their projects as far as possible with the materials available. Depending on the realism of the problem statement as well as the interest and budget of decision makers, it may be possible to have physical plant carry out some suggestions beyond student capacity such as painting.

Step 6. After the wayfinding installation is complete, invite parents and visitors to come and test the students' design work. Ask the visitors to follow the route and assess if the wayfinding features improve the visitors' ability to find their way. Encourage the visitors to share real, constructive feedback. Visitors may then share this with the class, and the class may reflect on the visitors' findings and make improvements as appropriate.

Example related mathematics CCSS

This project can be conducted at any elementary grade level, even kindergarten. Early geometry is incorporated into wayfinding as students help others find their way through the school (e.g., K.G.A.1 Describe objects in the environment using names of shapes, and describe the relative positions of these objects using terms such as above, below, beside, in front of, behind, and next to). Many other standards can be clustered here. Kindergarteners may be asked to add the total number of floor tiles along the pathway (e.g., K.OA.A.2 Solve addition and subtraction word problems, and add and subtract within 10, for example, by using objects or drawings to represent the problem). Kindergarteners can also group objects into categories as the building may have variances aligned with different grade levels or important locations such as different tile near the library (e.g., K.MD.B.3 Classify objects into given categories; count the numbers of objects in each category and sort the categories by count). As with the other projects, teachers at various elementary grade levels will find it easy to cluster a variety of standards they need to teach into this challenging project.

Conclusion

There is a great deal that teachers can do to nurture STEM potential among gifted elementary students including the important areas of math achievement, creativity, and spatial ability. While creativity has been in decline, international mathematics benchmarks suggest mediocrity in the United States, and spatial ability has not been well-developed in schools, architectural projects can be part of the solution. A variety of projects has been offered, easily tailored for all elementary grade levels and designed to challenge the gifted. Teachers can tailor and extend problem statements to meet the demands of their particular classroom settings. Moreover, teachers can use the examples along with the scale, discipline, and social or cultural context menu of ingredients offered to create a plethora of projects to meet the CCSS in mathematics while incorporating creativity and spatial challenge.

Conflict of Interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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