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Classroom Architect: Integrating Design Thinking and Math

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Abstract: Classroom Architect is a project-based curriculum that uses the principles of design thinking to review mathematical concepts, such as measurement, scale and area. The anchor task in this curriculum is to create a 3-D virtual model of the ideal classroom, based on the data the students collect. The curriculum uses design thinking as leverage to help students transfer classroom knowledge to real world problem-solving situations. Specifically, the students go through design thinking process -- user needs discovery, ideation, prototype and redesign. In each step of the process different mathematical concepts are reviewed and reinforced through their application to the task. The students will present their final prototype, justifying their design decisions, and mathematical calculations. Classroom Architect promotes an enduring understanding of key concepts of both design thinking and mathematics. It focuses on the learning of cognitive skills, such as problem solving, flexible thinking, making connections, representation of material in multiple ways, collaboration and application of mathematical concepts and skills to develop solutions. The curriculum is developed by applying Wiggins and McTighe's Backward Design method, with six design imperatives, (i) Knowledge Transfer and Application, (ii) Experiential Learning, (iii) Multiple Entries to Learning and Mastery, (iv) Scaffolds that Enable, (v) "Fit For Purpose" Assessment and (vi) Technology that Inspires Learning.

Keywords: Design curriculum, Design education for non-designers.

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Introduction

Relevance and Accountability for 21st Century Learning

In "Curriculum 21: Essential Education for a Changing World", Heidi Hayes Jacobs cautioned, "Curriculum should not only focus on the tools necessary to develop reasoned and logical construction of new knowledge in our various fields of study, but also should aggressively cultivate a culture that nurtures creativity in all our learners" (Hayes Jacobs, 2010, p. 17). In their work to improve classroom teaching, teachers therefore need to be bold advocates for helping students develop creative ideas that are actionable, rational and constructive.

Yet much of today's education system still focuses on guiding students toward finding the correct answers to fill-in-the blanks on standardized tests, as this kind of instruction facilitates streamlined assessments to measure success or failure. Van Dam (2003) states, "Many districts are so overwhelmed and concerned about the No Child Left Behind requirements and potential financial repercussions of not complying, that for lots of them the safest route is the 'back-to-basics' approach-focusing entirely on 20th century skills at the expense of 21st century ones." It is critical that the "banking" model of learning does not continue to prevail because in this concept of education the scope of action allowed to the students extends only as far as receiving, filing, and storing the deposits (Freire, 1993, p. 72).

In fact, a holistic, constructivist, child-centered approach to education does not end with shifts to a standardized, subject-specific, back-to-basics curriculum. These shifts represent changing priorities: relevance and accountability, and one way to increase relevance while maintaining accountability is to adopt an integrated approach (Drake, 2007). That is why through the implementation of a curriculum that integrate design thinking and math, "Classroom Architect: Integrating Design Thinking and Math" strives to help students develop a skill set that includes ideas generally not fostered within traditional school settings (see Figure 1 for framework and Figure 2 for Curriculum Summary). This skill set would produce an overall creative confidence in students by encouraging non-traditional problem solving skills and creative thinking. More importantly, through design thinking the curriculum hopes to engage students in new ways of thinking with which to deepen Mathematical understandings – beyond mere mastery of computational speed and proficiency. In fact, Kafai & Resnick (2002) and Todd (1999) suggest that design thinking skills are not merely extras, but can in fact aide students in core subject areas as well as building cognitive and social skills. It is therefore the aim of this curriculum product to explore and actualize the potential of Design Thinking in deepening mathematics learning in the classroom. The purpose of this article is to introduce this unique curriculum, and to share its design process and design imperatives with educators and design education researchers for constructive feedback.

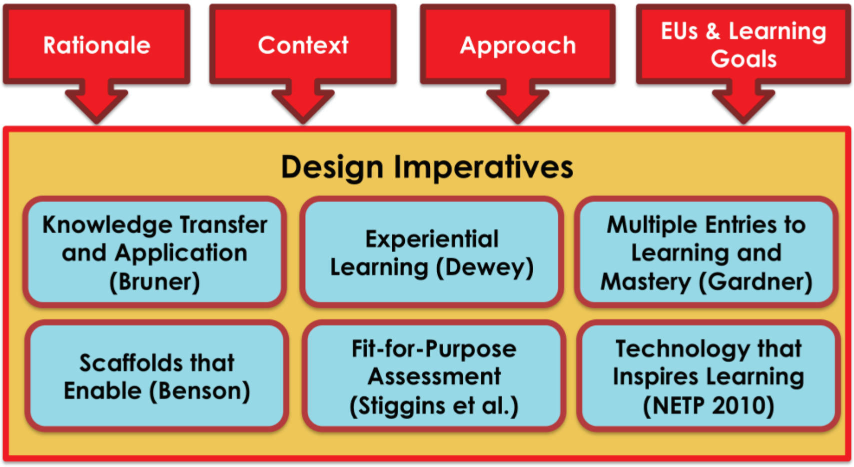

Figure 1. Curriculum Framework for Classroom Architect

Rationale / Context	
Curriculum for 21st Century Learning • Develop 21st Century Skills • Deepen understanding of academic content knowledge through real-world application	**The School** • School's philosophy: "Every Child is a Learner" -- to engage in standards-based skills and inquiry learning, solving real-world problems. • Twenty-nine 5th graders • All students on either free or reduced lunch • 17 students classified English Language Learners (ELLs).
Approach	
Integrating Design Thinking and Math • Solving Design Challenge using Design Thinking Process adapted from Stanford d.School. • Review of Math concepts taught.	
EUs and Learning Goals	
Students will understand that: • Good design solutions serve the needs of their users. • Ratios, proportions and scale factors are used to solve problems encountered in everyday life. • Area is used to represent the size of a two-dimensional space.	Learning Goals • To help students see connections between what they learn in math and problem solving in the real world through design thinking. • To review already taught standards in Math.
Design Imperatives	
Knowledge Transfer and Application (Bruner) Experiential Learning (Dewey) Multiple Entries to Learning and Mastery (Gardner) Scaffolds that Enable (Benson) Fit-for-Purpose Assessment (Stiggins et al.)	

Technology that Inspires Learning (National Education Technology Plan 2010)	
Lesson Components	**Assessment**
User Needs: Students interview their fellow students and the teacher to assess what they need in a classroom setup.	Assessment *for* learning: • Teacher feedback and monitoring of student progress (Catch Up Days) • Group Process Portfolio • Individual Design Journals
Ideation: Students take basic measurements of the room and furniture and brainstorm many redesign ideas.	
Prototype: Students use their Blueprint to rearrange classroom and add furniture.	Assessment *of* learning: • Final Prototype presented during Expo • Final Group Process Portfolio • Final Individual Design Journals
Redesign: Students get feedback on their Blueprint and redesign to create their final Prototype (3D virtual model)	
EXPO and Celebration	
Peer Assessment Using Rubrics A celebration of student success	

Figure 2. Curriculum Summary for Classroom Architect

Overview

For students, the classroom is a place for learning, an environment dedicated to promoting feelings of well-being and motivation to learn and focus. In fact, the classroom space offers both fertile ground and topic for students to bring creative thoughts to the process. Dunn and Burke (2009) stated the need for teachers to be taught how to redesign their classrooms so that all students will be provided the necessary space that complements their environmental learning style preferences. By altering the classroom some students will be given the opportunity to work in formal areas – desks, chairs, and tables; other students will choose informal areas – couches, rugs, soft chairs. Within the areas of every classroom, adaptations can be made for sound preferences, lighting needs, and temperature controls.

In “Classroom Architect: Integrating Design Thinking and Math”, the curriculum puts the students in that role instead. The classroom is a space for them to move around, a space for identity, a space for community-building and a space with working areas that fit the individual student. This experience would present them opportunities for greater ownership and motivation as learners.

Classroom Architect is a project-based curriculum that uses the principles of design thinking to review mathematical concepts, such as measurement, scale and area. The anchor task in this curriculum is for the students to each create a 3-D virtual model of their ideal classroom, based on the data they collected as a group. In this curriculum, the design thinking process the students go through is a simplified form (see Figure 3) of the approach developed by Stanford University’s d.school (refer to Figure 4). In this adaptation, the steps have been renamed while ensuring high fidelity to the key stages of the design thinking process. The changes are necessary because the language of the design thinking process becomes the language of communication and self-reflection as well. By simplifying the steps and renaming them to align with the key concepts of “user needs”, “ideation”, “prototype” and redesign” it would help these ideas stick and help the students experience greater success with the process of redesigning their classroom. The four steps are as follow:

- Step 1: User Needs Discovery
  Students interview fellow students and the teacher to assess what they need in a classroom setup.
- Step 2: Ideation
  Students take basic measurements of the room and furniture and brainstorm many redesign ideas.
- Step 3: Prototype
  Students create their first 2-D blueprint of their classroom design.
- Step 4: Redesign
  Students get feedback on the 3-D Virtual Model and create a final prototype of their classroom design.

In each step of the process different mathematical concepts are reviewed and reinforced through their application to the task. At the end, students will present their final prototype to the class, justifying their design decisions, and mathematical calculations.

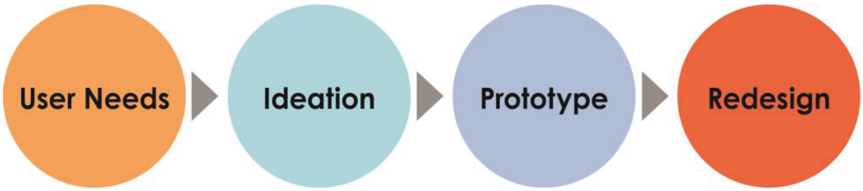

Figure 3. Design Thinking Process adapted from Stanford d.school's approach

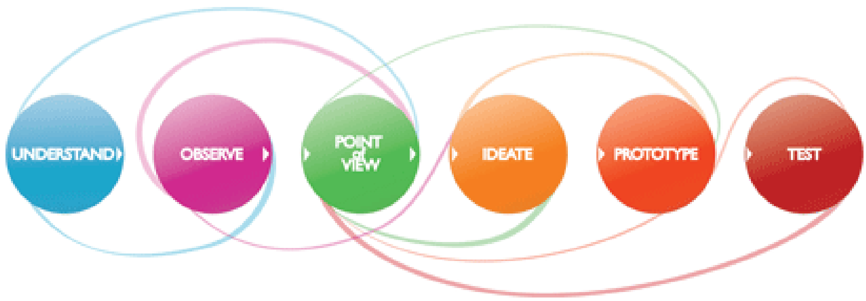

Figure 4. Stanford d.school's Design Thinking process (from: www.designthinkingblog.com/wp-content/uploads/2009/10/Design-thinking-process.png)

Information about the Site

About the School

The chosen site is a school in Southern California. The school's philosophy of "Every Child is a Learner" drives their commitment to developing instruction that provides students opportunities to engage in standards-based skills and inquiry learning, grappling with real-world problems, and seeking answers to their own questions. The school's overall approach to learning and teaching is driven by the following imperatives:

- A standards-based curriculum, best strategies, and differentiated instruction enable students to develop analytical and critical thinking skills.
- Learning and communicating through different modalities, and working individually and in groups, enables every student to learn.
- Mastering and developing knowledge in all subject areas prepares students for higher learning.
- Students learn to Make Good Choices about their learning in a positive school community.

About the Students

The project team has chosen to develop a curriculum for the school's 5th Graders, aged 10 to 11. There are 29 students (13 males, 16 females; 17 Hispanics, 3 Pacific Islanders, 8 African Americans, and 1 white). Seventeen students are classified English Language Learners. This is quite a varied class where students come with different learning abilities, styles and interests. Helping all students succeed in their learning is therefore an enormous challenge that requires innovative thinking. Therefore, instead of simply "teaching to the middle" by providing a single avenue for learning in the classroom setting, their teacher splits the class into two heterogeneous groups to be taught by two different teachers. Every Tuesday, both teachers would teach math to the whole class together.

Another key point of consideration is that many of these students are struggling math learners. These children have experienced little success with math and it is the goal of this curriculum to help them build confidence in learning the subject by using math to solve real-world problems – this potentially circumvents the problem of them encountering repeated failure and pressure of getting their answers right when solving math problems. In fact, Huinker (1998) makes the case for contextual problems and for letting students develop their own methods of computation with math. According to him, this allows students to have a firm understanding of math concepts – not computational algorithms that can rapidly become superficial.

Also using design thinking as a scaffold allows the English Language Learners to construct their own meaning of abstract math concepts without fear of judgment while they are actively applying math skills and knowledge through the trial and error process of design. Bruner has highlighted that notions of mathematical concepts can be made accessible to children of seven to ten years of age, "provided that they are divorced from their mathematical expression and studied through materials that the child can handle himself" (Bruner, 1960, p.43). Moschkovich (1999) also asserts that mathematical discourse is more than vocabulary and technical terms. That is why in Classroom Architect, it is encouraged for the teachers to let the children use their own terms of mathematical understanding to engage in collaborative problem-solving work, thus bringing them into a level playing field with their classmates.

About the Teacher

The teacher of chosen site is an educator who brings enthusiasm and a passion for teaching to her class every day. Being trained in the Design Thinking approach at the Stanford University d.school, she is excited about using the learning model to design challenging curriculum to deepen learning and empower her learners as change agents. The teacher does not expect that the themes will directly transfer until she explicitly teaches and links them to content and context. Through this curriculum the teacher would have the opportunity to integrate the processes of Design Thinking into academic content curriculum while working to achieve state standards.

Curriculum Objectives

The curriculum is designed to promote an enduring understanding of key concepts of both Design Thinking and mathematics. It focuses on the learning of cognitive skills, such as problem solving, flexible thinking, making connections, representation of material in multiple ways, collaboration and application of mathematical concepts and skills to develop solutions. To help students arrive at these outcomes, the curriculum is developed with Wiggins and McTighe's Backward Design method (refer to Figure 5). The approach presented a helpful way to think about what understandings the curriculum want the students to gain, how to design for them, and how to find evidence of these understandings in student work (refer to Figure 6 for the overall curriculum schedule and lessons. For more detailed lesson plans and learning materials contact the authors).

Stage 1: Desired Results	
Established Goals	**Standards**
To help students see connections between what they learn in math and problem solving in the real world through design thinking.	Listed in individual lesson plans. The curriculum is designed to review already taught standards.
What overarching understandings are desired?	**What are the overarching "essential" questions?**
Students will understand that: 1. Good design solutions serve the needs of their users 2. Ratios, proportions and scale factors are used to solve problems encountered in everyday life. 3. Area is used to represent the size of a two-dimensional space	1. Why do some design solutions work and others don't? What makes a design solution a good one? 2. How can ratios, proportions and scales be used to solve problems in everyday life? 3. How can the size of two differently shaped physical spaces be compared using the concept of area?
Students will know… 1. Design thinking process: stages that they go through in developing their solution 2. Mathematical knowledge: • Scale factors (ratios) are used to create scale drawings. • Area is used to compare the sizes of different two dimensional spaces	Students will be able to… 1. Use information-gathering skills like research and interviewing to find out what their users need 2. Test their ideas using prototyping and refine their ideas with the feedback provided 3. Develop skills with ratios, scale, and area and apply them in the redesigning the classroom project 4. Use ratios to express scale
Stage 2: Assessment Evidence	

Performance Task	Other evidence…
Culminating Performance: • In your teams, your task is to redesign the classroom to best meet the needs of everybody who uses it. What would it look like? • Who uses your classroom? How do you know that your solution would create better learning environment? • Present your solution to your class. Convince them that your solution is the one to be implemented.	Formative Assessment: • Individual Design Journals • Group Process Folder: ○ Interview Questions/Notes ○ User Needs List ○ Measurement Chart ○ Original Blueprint ○ Ideation List Summative Assessment: • Final Presentation • Final Prototype 3D Model • First Prototype 2D Blueprint Observations of group processes (meetings etc.) and dialogue with student groups

Figure 5. Development of Classroom Architect Curriculum Using Backward Design

Week 1 - Discovering User Needs and Current Classroom Model:

Interview and User Needs

- Day 1: Classroom Architect Project Design Launch (1hr 30mins)
- Day 2: Interviewing to identify User Needs (1hr 30mins)

Current Classroom Blueprint

- Day 3: Room Measurements (1hr)
- Day 4: Scaled Classroom Representation (1hr 30mins)
- Day 5: Conference & Catch Up Day (1hr 30mins)

Week 2 - Ideation and Prototype:

Ideation & Software Introduction

- Day 1: Ideation (1hr 30mins)
- Day 2: Narrow Down Ideas & Software Introduction (1hr 30mins)

Virtual Prototype

- Day 3: Work on Prototype (1hr)
- Day 4: Work on Prototype & Virtual User Test (1hr 30mins)
- Day 5: Conference & Catch up Day (1hr 30mins)

Week 3 – Expo:

Expo

- Day 1: Expo Preparation & Prototype Completion (1hr 30mins)
- Day 2: Expo, Ballot & Celebration (1hr 30mins)

Figure 6. Overall curriculum schedule and lessons

Integrating Design Thinking and Math Learning

This curriculum uses design thinking as leverage to help students transfer classroom knowledge to problem-solving situations in the real world. In most math curricula mathematical concepts are taught in isolation and as a result students do not view math as an integrated whole – and thus they do not understand its relevance and importance. According to Van de Wall (2001), mathematical ideas are “important” if they are useful in the development of other ideas, link ideas one to the other, or serve to illustrate the discipline of mathematics as a human endeavor. In the classroom, a strict algorithmic focus on teaching and learning math has unfortunately undermined the real enduring understanding the students to get out of studying math. Algorithmic procedures are helpful in conducting routine tasks easily but the most skillful use of a procedure will not help develop conceptual knowledge that is related to that procedure (Hiebert, 1990). Doing endless multiplication exercises will not help a child understand what multiplication means and what it is used for. In the real world, mathematicians are concerned less with algorithmic memorization and computation, but more with creative problem solving.

This is where the design process can come into play. Design Thinking is an approach to learning that focuses on developing children's creative confidence through hands-on projects that focus on empathy, promoting a bias toward action, encouraging ideation and fostering active problem-solving (Carroll et al., 2010). It fosters iterative problem solving and solution generation, making it relevant to projects in academic subjects while adding an inventive imperative highly consistent with 21st century skill sets[1].

In fact, design thinking can provide powerful tool to help students learn mathematics with understanding. With design thinking embedded in the mathematics curriculum, students are required to evaluate their own ideas and ideas of others, are encouraged to make mathematical conjectures and test them and develop their reasoning skills. More importantly, the notions of mathematical concepts can be made more accessible to English language Learners because in a design project these concepts are "divorced from their mathematical expression and studied through materials that the child can handle himself" (Bruner, 1960, p.43).

Moreover the design thinking process moves beyond problem solving and project-based work by including a human-centered approach. With a focus on addressing user needs, learning therefore becomes an active endeavor of students that takes place in an environment that stresses problem-solving, reasoning, and thoughtful interaction among students.

Curriculum Design Imperatives

i. Knowledge Transfer and Application

According to Bruner, in The Process of Education (1960), the best way to create interest in a subject is to render it worth knowing, which means to make the knowledge gained usable in one's thinking beyond the situation in which the learning has occurred" (p. 31).

The Design Thinking model of learning can provide learners the platform to apply knowledge and concepts and enable teachers to go beyond the standard ordinary didactic teaching approaches towards more engaged learning. This curriculum explores how to bridge the gap between the theoretical and reality. Through Design Thinking, the curriculum attempts to make concepts learned in the classroom relevant to the real world and provides opportunities to apply the knowledge and skills acquired on solving real-world problems. The clarity of such reality-based links is also more likely to drive greater engagement in learning. That is why this curriculum focuses on an authentic

[1] These include innovation, creativity, critical thinking, problem solving, communication, and collaboration skills (Partnership for 21st Century Skills, 2009).

challenge that drives students to explore the core concepts and principles of Math[2] in a familiar classroom setting. The design challenge requires the children to explain and defend their solutions and in so doing can have a positive effect on how they view mathematics and their own mathematical abilities. Justification of responses mathematically forces students to think reflectively and eliminates guessing or responses based on rote learning.

Next, Moschkovich (1999) highlights that it is important for the teacher to model consistent norms for discussion but it is more important for the teacher to "revoice" student contributions, building on what they say and probing what they mean. That is why in addition to the design thinking process and authentic project task, the curriculum strongly encourage the teachers not to enforce a strict regimen of using accurate mathematical language throughout the redesign process.

ii. Experiential Learning

This curriculum takes an approach that places the students in the active role of design thinkers. According to Dewey (1938), education needs to be based upon the experiences and the interests of the student. More importantly on the quality of experience that is educative for them. This curriculum is inspired by his ideas that "every experience is a moving force" (p. 38), and that "every experience both takes up something from those which have gone before and modifies in some way the quality of those which come after" (p. 27). In this curriculum, the students are provided with a deeper experience of the content, concept and issues they have learned through experiential learning. This will enable the students to be exposed to issues, simulations, concepts and theories in a way that they have never been exposed to before. It will help students to move from just knowing facts to understanding and appreciating them – the curriculum also tries to ease and facilitate this process by trying to capture students' prior experience and to build upon it in order to propel them to learn more in and out of the classroom. By engaging students actively in the role of design thinkers, this curriculum hopes to make the experience meet their internal needs, interests or goals.

iii. Multiple Entries to Learning and Mastery

To celebrate a culture of innovation and motivate the development of diverse talents, this curriculum takes an approach that also seeks multiple entry points for understanding of the students to take place. According to Gardner (1999):

> [I]ndividuals possess different kinds of minds, featuring different blends of mental representations. People will, consequently, approach and master curricular materials in quite idiosyncratic ways…. [The] approach weds the theory of multiple intelligences to the goal of enhanced performances of understanding" (p.133)

This vision for teaching and learning in the 21st century reflects a curriculum of processes that serve as the leverage for learning academic content. It is a curriculum that provides the learners the opportunity to engage with a situation of dilemma and

[2] In each lesson plan for Classroom Architect, key math concepts according to K-12 California's Common Core Content Standards for Mathematics (from: http://www.scoe.net/castandards/agenda/2010/math_ccs_recommendations.pdf) are identified. For example, in a lesson where students need to measure the classroom, their ability to accurately read a ruler and to what amount (e.g. in ½ and ¼ inch) is monitored. Also when they each need to draw a blueprint, understanding of scale and unit conversion skills are required.

thus allowing them to tap into different intelligences – logical-mathematical, linguistic, spatial, interpersonal and intrapersonal – and bring to fore the multitude of dispositions and strengths needed to develop innovative and effective solutions that meet the real needs of their users.

iv. Scaffolds that Enable

A key feature of Classroom Architect is that it is structured around helping the teacher to scaffold support for the learners so that the responsibility of learning would reside increasingly with the learner – which is in line with the school's vision. More importantly, scaffolding helps to build upon what the students already know to help them navigate the challenges that come with the new project task. In fact, if scaffolding is properly administered, it will act as an enabler, not as a disabler (Benson, 1997). To ensure success with instructional scaffolding, Lange (2002) identified two major steps: first, development of instructional plans to lead the students from what they already know to a deep understanding of new material and secondly, execution of the plans, wherein the instructor provides support to the students at every step of the learning process. That is why the lessons in this curriculum always include the teacher modelling a familiar task or concept that the student is still not confident to grasp independently before letting the children handle the tasks independently.

v. "Fit For Purpose" Assessment

In Understanding by Design, Wiggins and McTighe explain how curriculum and instruction promote higher order learning and deep understanding through a systematic approach to curriculum development beginning with identifying the course objective and then developing appropriate assessment matched to the objective. In fact, in developing the assessment modes and rubrics, this curriculum is mindful that they must be "fit for purpose". Indeed, in Assessment Manifesto: A Call for the Development of Balance Assessment Systems, Stiggins (2008) asserts that to yield dependable results, regardless of the context of their use, assessments must meet these standards of quality: They must be designed to serve a specific predetermined purpose, arise from a specific predetermined definition of achievement success, be designed specifically to fit into each particular purpose and target context, and communicate their results effectively.

The culminating performance of this curriculum is a class expo. It is believed that the students will feel a greater sense of ownership of what they create and will try harder to make it as good as possible because it will be seen by a larger audience. They learn to take responsibility for evaluating their own efforts rather than waiting for the teacher to pass judgment on them.

However, this curriculum also takes an approach that assessment should be an on-going process where students receive timely feedback so tat they can make continuous improvement toward the achievement of high standards and desired learning outcomes.

Critical checkpoints will be identified throughout this process. The curriculum encourages the power of learner autonomy and proposes that the students' performance and design thinking mind-sets be assessed through self-and-peer assessments. However an accurate assessment of content understanding should still be carried out by the teacher and thus it will continue to be a role of the teacher to monitor the students' learning and provide just-in-time feedback to move the students toward the acquisition of enduring Math ideas and skills on which the curriculum focuses. That is why every Friday is reserved as Catch Up day where teams can work with each other and the teachers to work towards greater progress and gain assurance that they are on the right track.

vi. Technology that Inspires Learning

The model of 21st century learning calls for engaging and empowering learning experiences for all learners. As educators, it is necessary to bring state-of-the art technology into learning to enable, motivate, and inspire all students, regardless of background, languages, or disabilities, to achieve.

The National Education Technology Plan 2010 released by the US Department of Education has challenged the education system to leverage the learning sciences and modern technology to create engaging, relevant, and personalized learning experiences for all learners that mirror students' daily lives and the reality of their futures.

Against a backdrop where standards-based competencies still form the basis of what all students should learn, it is hopeful that technology is a powerful tool that provides students greater options for engaging in learning and inspires higher levels of motivation and achievement. In this curriculum, therefore an online freeware Sweet Home 3-D is included to facilitate their articulation and expression of ideas and, more importantly, collect evidence of their knowledge and problem solving abilities as they work.

Assessment Framework

The assessment in this curriculum aims to provide both the students and teachers an indicator of whether the students have achieved the expected learning outcomes. During the two and a half weeks, the students have to demonstrate their ability, individually and as a group, by applying the knowledge of both design thinking and math to develop the project task.

i. Areas Assessed

Students are expected to demonstrate the ability to generate, develop and evaluate ideas and information so as to apply both design thinking skills and mathematical knowledge as they develop their project task of redesigning their classroom. They will be assessed in the following areas:

(i) Identification of user needs
(ii) Development of ideas and solutions to meet these user needs
(iii) Application of Mathematical concepts

ii. Means of Assessment

Students will be assessed on their performance both as members of their group and as individuals. Assessment is made of students carrying out the project and of the final products delivered. The performance of individual students and that of groups is assessed through the following means:

- Group process folder
- Blueprint
- 3-D Virtual Model

iii. Communicating about Student Learning

In this curriculum, one key consideration is that the assessment information should motivate students to put in efforts and do better – even after the project. It is accepted that assessments with grades assigned usually have strong motivational effects and any work which has no score figured into the final grade may not encourage students to invest time and efforts. In "Classroom Assessment for Student Learning: Doing It Right – Using It Well", Stiggins et al (2006) assert that "this system of motivation does not work well for all students; most noticeably it does not work for students who are performing marginally or those who are failing." In fact the group of assessment experts advocate reducing evaluative feedback and increasing descriptive feedback to affect motivation and achievement.

This means that there must be strong principles of assessment for learning put in practice to develop an internal sense of motivation in students. The assessment this curriculum adopts is therefore criterion-based to help students keep improving with the availability of frequent feedback from peers and teachers to attain the desired level of achievement. As a result of this process, students would have clearer and reinforced learning targets, constantly receive feedback about where they are in relation to the targets, and are able to make changes to reach higher levels.

iv. Assessment Rubrics

In Classroom Architect, a set of assessment rubrics for both students and teachers is provided as an authentic assessment tool to help students make progress and measure their final work (see Figure 7 and 8). These rubrics would be handed out at the beginning and highlighted at appropriate checkpoints to get students to think about the criteria on which their work will be judged.

Classroom Architect would provide them a new assessment experience where they can be acclimatized to receiving descriptive feedback rather than evaluative feedback. For a project-based and process-oriented task, this also helps the teacher provide a picture of learning that is more accurate and more meaningful. Again Stiggins et al (2006) emphasize that if the objective is to communicate thoroughly about student achievement then the educators should not simply convert rubric scores to letter grades. Rather, they recommend that teachers communicate using the points on the rubric – indeed the description of the performance allows us to provide more clear and focused feedback. More importantly, it is unauthentic to combine the scores for the different categories of user needs and application of mathematical concepts into a single score or grade. If the curriculum was to treat the students like real-word designers, helping them understand the areas of improvement is more critical than helping them make sense of a final score. "Stigmatizing" them by labeling their work with a score does not help them focus on bettering themselves but may instead make them rank their work in comparison with the achievement of others – just like any other math assignment or test they have always had.

Davies (2009) believes it is important to involve students in the assessment process. When students are involved in the classroom assessment process, they are more engaged and motivated, and they learn more. One way of involving students in the process is to allow them to co-construct criteria that will be measured in assessments. That is why in the assessment rubric the teachers and students work out the criteria for "Creativity and Design" largely because this is an area where student input could potentially spur them to deliver their best for the final prototype. It is also a category where criteria could be more easily developed.

Finally every student will receive a Personal Design Journal as a way of encouraging them to share (orally and in writing) with both the teacher and fellow students their thoughts and learning, and assist them in becoming reflective learners. It also provides the teacher with information on what each student has learned and what each student has difficulties learning. In addition, they can see their progress over time because they have a tangible record of their learning.

Group Assessment (Group Process Portfolio and Blueprint)

		Novice (1)	Intermediate (2)	Expert (3)
User Needs	Group Process Portfolio	Shows limited understanding of users' needs with little/no explanation.	Shows understanding of users' needs with links to interview responses.	Shows deep understanding of user's needs by demonstrating how a more generalizable user need fits with their interview responses.
	Blueprint Prototype	Creates a prototype that demonstrates limited evidence of testing and limited understanding of user needs.	Creates a prototype that demonstrates understanding of user needs, tests specific aspects of their idea and leads to further iteration.	Creates a prototype that demonstrates clear understanding of user needs, tests for constructive feedback and leads to further iteration and deeper understanding of the user.
Application of Mathematical Concepts	Group Process Portfolio	The group process portfolio addresses none of the mathematical components presented in the task.	The group process portfolio addresses some but not all of the mathematical components presented in the task.	The group process portfolio puts to effective use the underlying mathematical concepts upon which the task is designed.
	Blueprint Prototype	The prototype addresses none of the mathematical components presented in the task.	The prototype addresses some but not all of the mathematical components presented in the task.	The prototype puts to effective use the underlying mathematical concepts upon which the task is designed.

Figure 7. Group Assessment Rubrics

Individual Assessment (3D Virtual Prototype)

	Novice (1)	Intermediate (2)	Expert (3)
User Needs	Creates a prototype that demonstrates limited evidence of testing and limited understanding of user needs.	Creates a prototype that demonstrates understanding of user needs, tests specific aspects of their idea and leads to further iteration.	Creates a prototype that demonstrates clear understanding of user needs, tests for constructive feedback and leads to further iteration and deeper understanding of the user.
Application of Mathematical Concepts	The prototype addresses none of the mathematical components presented in the task.	The prototype addresses some but not all of the mathematical components presented in the task.	The prototype puts to effective use the underlying mathematical concepts upon which the task is designed.

Figure 8. Individual Assessment Rubrics

Discussion

Classroom Architect has been developed in the hope of achieving goal of disseminating design thinking among young students. Also to deepen understanding of mathematical concepts by applying them to real world problems by ways of solving design problems. The curriculum has been developed with keen interest in the actual students and the teacher who would conduct the curriculum in the belief that the genuine understanding of the audience would render it with authenticity and effectiveness. However, the curriculum has been designed with philosophy and imperatives that is universal so that it could be adapted in broader circumstances.

The next steps for the Classroom Architect would be to gather data from actual use in the classrooms to test its feasibility and to further improvements, also to try fusing design thinking with other classroom subjects.

References

Bruner, J. 1960. *The Process of Education*. Cambridge: Harvard University Press.

Carroll et Al. 2010. “Destination, Imagination and the Fires Within: Design Thinking in a Middle School Classroom”. The entity from which ERIC acquires the content, including journal, organization, and conference names, or by means of online submission from the author.International Journal of Art & Design Education, 29(1), 37-53.

Davies, Anne. 2007. “Involving Students in the Classroom Assessment Process”. In *Ahead of the curve: the power of assessment to transform teaching and learning, edited by* D.B. Reeves, pp. 183-204. Bloomington, IN: Solution Tree.

Dewey, J. 1938. *Experience and Education*. New York: Collier Books, pp. 25-50.

Freire, Paulo. 1980. *Pedagogy of the Oppressed.* New York: Continuum.

Gardner, H. 1999. *The Disciplined Mind*. New York: Penguin Books. pp. 32-40.

Hayes Jacobs, H. 2010. Curriculum 21: Essential Education for a Changing World. Alexandria, VA: ASCD.

Hiebert, J. 1990. "The role of routine procedures in the development of mathematical competence". In *Teaching and learning mathematics in the 1990's. 1990 Yearbook of the National Council of Teachers of Mathematics*, edited by T. J. Cooney, pp. 31-40. Reston, VA: National Council of Teachers of Mathematics.

Huinker, D. M. 1998. Letting fraction algorithms emerge through problem-solving. In *The teaching and learning of algorithms in school mathematics*, edited by L. J. Morrow, pp. 170-182. Reston, VA: National Council of Teachers of Mathematics.

Kafai, Y., and Resnick, M. 2000. Constructionism in practice: designing, thinking, and learning in a digital world. Mahwah, NJ: Lawrence Erlbaum Associates.

Lange, V. L. (2002). Instructional scaffolding. [Cited on February 25, 2011]. Available from http://condor.admin.ccny.cuny.edu/~group4/Cano/Cano%20Paper.doc

McTighe, J., and Wiggins, G. 1999. The Understanding by Design Handbook, Alexandra, VA: Association for Supervision and Curriculum Development.

Moschkovich, J. N. 1999. Supporting the Participation of English Language Learners in Mathematical Discussions. *For the Learning of Mathematics,* 19(1), 11-19.

National Education Technology Plan 2010. 2010. [Cited on February 25, 2011]. Available from http://www.ed.gov/technology/netp2010

Stiggins, R.J. 2008. Assessment Manifesto: A Call for the Development of Balance Assessment Systems. A position paper published by the ETS Assessment Training Institute, Portland, Oregon.

Stiggins, R., Arter, J., Chappuis, J., and Chappuis, S. 2006. *Classroom assessment for student learning: Doing it right – Using it well*. Portland, OR. Educational Testing Service.

Todd, R. 1999. Design and technology yields a new paradigm for elementary schooling. *Journal of Technology Studies*, *25(2)*, 26-33.

Van Dam, J. 2003. In J. Salpeter, 21st Century Skills: Will Our Students Be Prepared? [cited 22 December 2009]. Available from http://www.techlearning.com/article/13832

Van de Walle, J. 1997. Elementary and Middle School Mathematics: Teaching Developmentally (3rd edition). New York: Longman.