Title: Constructing Algebra 2

Length of Course: Full Year (2 semesters; 3 trimesters; 4 quarters)

Subject Area – Discipline: Mathematics ("c") – Algebra 2

CTE Sector: Building and Construction Trades

CTE Pathway: Residential and Commercial Construction

Grade Level(s): 9-12

Course Overview:
In this course, Advanced Algebra 2 standards are combined with the Building Trades and Construction Industry Sector concepts into an integrated secondary course that meets both Algebra 2 course requirements and CTE standards. The course follows a contextualized model, where "a - g" mathematics determines and drives occupational (CTE) curriculum. Mathematics is the gatekeeper for hands-on projects that result in construction of a scale model or an actual residential home. Seven thematic units encompass rigorous algebraic calculations that facilitate student construction tasks, resulting in the completion of a residential or commercial structure and its surrounding landscape features. Students completing this course will receive one unit of UC "c" mathematics that counts towards "a-g" admissions requirements. Students will also learn about career and college options in related fields.

Course Content:

Unit 1: Planning - Introduction to Functions
The process of planning and designing a structure is introduced first. Students will experience each step of the development process and outline appropriate sequencing of events as it applies to project scheduling. The process of creating a floor plan will allow the students to investigate math modeling and a variety of functions in practical applications. In addition, students will be justifying their decisions by explaining their design choices in writing.

Unit 1 - Assignments

1. Written Proposal for Site Plan: This assignment introduces the planning segment and should take roughly 1 day to complete. Students read a site plan to determine the best location of a structure and then write a proposal of approximately one page justifying the location and orientation of the structure on the site.

2. Maximum Space Calculations Diagram: This assignment introduces students to linear, quadratic, and higher degree polynomial functions. Students determine the most suitable

location on the site selecting from parabolic or trapezoidal lots of different sizes provided by the instructor. Students assess maximum and minimum values of functions based on maximizing rectangular spaces inside of the lots, and they create a table that will be submitted for formal assessment. Students must also draw the maximized space on their lot to turn in. Lots should be simplified structures to accommodate Algebra 2 skill sets.

3. 2-D Draft Plans Part I: This assignment serves as an introduction to conic sections.Students use conic sections to draw functions in the draft plan as represented in CAD. Students begin by providing domain/range of each function. Students will solve simple problems for conic sections in order to proportionally represent scale in the draft 2-D plan in preparation for the introduction of rational equations.

Unit 2: Site Work - Linear Functions/Linear Systems

The physical transformation of the site begins in preparation for building. During site work, the building process moves from two and three dimensional plans to three dimensional structures. Students will have prepared the site through surveying, levelling, and grading for the building foundation and other necessary site improvements. This process will allow students to begin investigating piecewise functions. The connection between systems of two equations and systems of three equations will be illustrated throughout the site work process, both in the work done on the plot of land and using the software program to create the 3-D plan. An essential part of this unit requires students to apply measurements from scale drawings to blueprint specifications.

Unit 2 - Assignments

1. **Topographical Map of Site:** *This assignment is an introduction to three-dimensional coordinates and matrices. It should take between 2 to 3 days to complete.*
   - Find and plot the elevation of the land both on site and on a map. (Students are introduced to three dimensional Cartesian coordinates based upon their results.)
   - Plot land elevation using stakes at land site
   - Plot 3-D elevation using classroom software such as Sketchup or similar software, as well as on a map of their own design
   - Use matrices from the points found to find the area of the space plotted
   - Provide directions to grade the lot for slope/drainage, calculating slope and using inverse trig functions to find the angle of depression
   - Map the footprint, roof line and orientation of the structure

2. Two-D Draft Plans Part 2: *This assignment expands upon knowledge about conic sections and introduces piecewise functions/relations from the 2-D draft plans in unit 1. It should take 1 to 2 days to complete.*
   - Using the floor plan, state the domain and range for each of the functions that comprise the floor plan of the structure
   - Number each function and organize it on the page as part of a piecewise relation

3. Drainage Diagram and Grading Summary: *This assignment builds upon linear piecewise functions. It should take 1 to 2 days to complete.*

- Create a report on how lot grading is accomplished on a particular site
- Create a piecewise function to represent the difference between slope used to build on compared with the slope used for drainage on the site

4. Passive Solar Building Model: *This assignment emphasizes slope, angles of elevation and depression, and basic trigonometry. It should take 1 to 2 days to complete.*

- Create a model for passive solar building on a site
- Observe the angle of the sun using various tools outdoors
- Plot a graph determining proper building orientation
- Demonstrate use of trigonometry to find the angle of orientation

5. Material Minimization Document: *This assignment introduces rational functions, and maximums/minimums to students. It can be extended to introduce the concepts of roots and y-intercepts. It should take 1 to 2 days to complete.*

- Create a document explaining how one can minimize material usage, optimizing the shape of soup and soda cans as an example
- Explore the volume and surface area of various soup and soda cans using tape measures on them, finding out which ones use the least amount of material Students create a data matrix of the information found
- Evaluate mathematically how to create the perfect can by using minimum values of a surface area given the volume. In doing so, students learn how to minimize materials in construction projects in general by changing the shape of the overall object. This assignment ties in with the projects that maximize space, and is really an extension of the space maximization projects that were more directly related to the main construction project
- Write an evaluation of what they've found, explaining how their findings can be used in construction

Unit 3: Foundation Systems - Quadratic Functions/Conic Sections

Every structure needs to have a solid foundation. In this phase, students first survey the site, excavate soil for the foundation, build wall forms, pour footings and stem walls, and install rebar for structural strength. Students prepare a plan with estimates for the foundation work. Students will use direct variation to calculate exactly how much dirt will need to be moved from the site. In addition, students continue to work with the site and floor plans, rewriting the plan as a series of piecewise functions on the Cartesian Plane. Continuing their work with the drawings from the previous chapters, and their investigations of conic sections, students will begin to see the connection between the equations of conic sections to the construction drawings created in Units 1 & 2, allowing the abstract idea of translating between equations and graphs to become much more concrete.

1. **Dealing With Dirt:** *This assignment spirals the linear function material emphasized in unit 2. It should take 1 day to complete.*

- Explain in writing and graphs the number of trucks needed to haul off dirt given dirt expansion when excavated in varying environments (higher or lower concentration of clay/sand)
- Discover the formulas experimentally using packed dirt that is then expanded.
- Plot points and graph how dirt expands after it's excavated
- Apply the findings for dirt expansion mathematically using direct variation, to find the amount of expansion
- Plot a graph displaying differences in the number of trucks needed depending upon the type of dirt to be removed
- Explore joint variation, , as an extension activity
- Scale Models: *This assignment expands upon conic sections of all types (parabolas and quadratic functions, ellipses, and hyperbolas). It should take 3 to 5 days to complete. It may be given as a homework project.*
- Produce a scale model of the drafted plans from Unit 1
- Revisit formulas for conic sections and proportions lay the foundation for their scale model based upon the drafted plans
- Expand upon knowledge based on the current step
- Complete conic section worksheet or bookwork to expand upon knowledge of the equations used to create shapes found in the scale model

2. **Concrete Estimates:** *This assignment reintroduces slope. It can be expanded to explain how leading coefficients affect functions. It takes between 1 and 3 days to complete. Note that this assignment is optional in a math-only course.*
- Estimate materials (concrete) usage based on the scale model and the amount of waste they might have during foundation phase
- Dig the footing following the perimeter of the building with a tractor, backhoe or shovels
- Haul away excavated dirt by truck
- Revisit the steps in slope and drainage

3. **Foundation Model:** *This assignment revisits linear functions and linear models. Linear regression can also be used during slump testing. It takes between 1 and 5 days to complete. Note that this assignment is optional in a math-only course.*
- Create models of footings and stem walls
- Compile information and create graph for slump tests of concrete and model the results with linear functions
- Relate the slump test to the strength of the concrete
- Determine the amount of concrete needed for footings and stem walls
- Build and install form boards to hold the concrete while it hardens
- Install rebar into the footing and stem walls
- Pour concrete

Unit 4: Framing Systems - Polynomial Functions/Rational Functions

Working with framing, students transform conceptual ideas and construction drawings into a real structure for the first time. The structure itself comes together during the framing process, starting with material selection, flooring, walls and roofing construction, tasks necessitating a review of trigonometric concepts. By the end of this unit, students will have constructed the entire framing for their structure. Students solve rational equations in their work using the scale model. Mathematical concepts require students to work with surface area, continuing their investigation of conic sections.

1. **Two-D Draft Plans Part III:** *This assignment nearly completes student knowledge of conic sections and piecewise relations (conic sections in standard form as part of a large piecewise relation). It should take 1 to 2 days to complete.*
   - Complete drawings, and find relevant mathematical functions that will eventually be used to create a scale model of their work
   - Determine the layout of a scale model from the drafted floor plan.
   - Complete the floor plan
   - Verify that all mathematical functions are exact (conic equations and linear functions are written)
   - State stretch factor, and domain/range for each equation
   - Plot the functions on graphical tool such as Graphmatica, Mathematica, KMPlot, etc.

2. **Floor system construction:** *This assignment introduces rational equations and rational functions to students. It should take 1 to 3 days to complete.*
   - Calculate scale using rational equations
   - Include rational equations in a writeup to be checked by teacher for accuracy
   - Complete worksheet on more complicated rational equations
   - Build a complete floor system which incorporates sills, floor joists, girders, and subfloors

3. **Frame Walls:** *This assignment continues the study of rational equations and rational functions. It should take 1 to 3 days to complete.*
   - Calculate scale using rational equations
   - Include rational equations in a writeup to be checked by teacher for accuracy
   - Complete worksheet on more complicated rational equations (building upon worksheet given in Key Assignment 2)
   - Layout wall plates and frame walls based on architectural drawings

4. **Calculate Building Area:** *This assignment completes student understanding of conic sections, and reviews general polynomial functions. It should take 1 to 2 days to*

complete.

- Find the surface area of the structure, utilizing knowledge of conic sections
- Complete conic section exercises in a worksheet or book to expand on what was learned in the application

5. **Diagram Roof Slope:** *This assignment spirals knowledge obtained regarding slope, angles of elevation and depression, and trigonometric functions. This could be expanded to cover other general trigonometry. It takes 1 to 2 days to complete.*

- Based on the site geography, incorporate right triangle trigonometry to locate the ideal solar panel positioning

6. **Build the Roof:** *This assignment continues the study of trigonometry in a real-world application. It takes 1 to 6 days to complete. This assignment is optional when only creating a scale model.*

- Construct the roof structure that accommodates solar panels

7. **Stair Construction:** *This assignment furthers the study of trigonometry, and revisits linear functions. It takes 2 to 5 days to complete.*

- Construct stairs; incorporate ramps that meet ADA requirements
- Find angle of elevation of the stairs using inverse tangent on slope of stairs

Unit 5: Exterior Enclosure - Radical Functions and Inverses

During this unit of study, the physical structure takes on aesthetic qualities. The exterior enclosure unit encompasses finishing the roof, building wrap, exterior wall finish material, and installing windows and doors on the structure. The mathematical components in this unit include precise measurements and working with scale from floor plans. As students calculate R-values for insulation, inverse variation will be explored. Students will continue the work they started in unit 1 with maximizing and minimizing areas of more complex plots of land, integrating the idea of inverses with polynomials and radicals.

1. **Historical Research Project:** *This assignment provides a history lesson in architecture, and can include a brief history of how mathematics developed with the evolution of architecture throughout history. This is best done as a research project outside of school, with a deadline of 1 to 2 weeks to complete (1 week if students are doing a quick write-up, 2 weeks if a full presentation of some sort is expected).*

- Research three different roof styles used in construction for a historical perspective
- Present research findings in class with modeling (i.e., balsa wood roof structures)
- Apply algebraic formulas for 'rise and run'
- Approximate roof styles for most energy efficiency according to location, climate, etc.

2. **Maximizing Space/Passive Solar Orientation:** *This assignment introduces inverse functions and radical functions by using plots of land similar to those in unit 1, but with the x and y positions of the land inverted. Polynomial functions are revisited as well, along with domain and range. This assignment should take 1 day to complete.*

- Analyze various pieces of real land on a teacher-provided PowerPoint presentation, and use data about sun orientation and shade covering to find the best location and orientation of a given structure. Group and class-level discussion of how higher mathematics can be used to maximize land usage. Team write-up on discussed topics
- Complete worksheet displaying lots that have simplified orientation (based on radical functions and trapezoidal layouts that represent inverse functions to those found in unit 1). Worksheet will include calculating inverse polynomial and linear functions of the provided lots, and calculating maximized space on the lots after finding the inverse functions
- Calculate constraints on the domain and range of the inverse functions

3. **Inverses/Radicals worksheet:** *This assignment completes student understanding of inverse functions by extending student knowledge of inverses in general. This assignment should take 1 day to complete.*

- Now that students have an understanding of the application of inverses and radicals, they will complete extra practice problems at increasing levels of difficulty

4. **Roofing:** *This assignment is meant for a full construction project only, and can be skipped if only scale models are being created. This assignment takes 1 to 8 days to complete.*

- Finish roof, this includes adding building paper and finished top surface. (i.e. shingles, tile, etc.) (CTE only)

5. **Title 24 Evaluation:** *This assignment continues the exploration of direct, inverse, and joint variation, focusing on inverse variation. This assignment takes 1 to 2 days to complete.*

- Insulate an area and produce a document detailing the R-value of different material. Note that the R-value is found by using the inverse variation formula , where L is the thickness of the material, and K is the thermal conductivity
- Create a table comparing the insulation value of various materials (i.e. solid wood doors compared to hollow doors and metal doors, or double-pane windows compared to single-pane windows)
- Use table to comply with energy efficiency standards as they relate to title 24 building codes

6. **Solar Windows and Doors:** *This assignment is meant for a full construction project only, and can be skipped if only scale models are being created. This assignment takes 1 to 4 days to complete.*

- Install passive solar items which include:
  - Double-pane windows
  - Doors

7. **Exterior Wall Covering:** *This assignment is meant for a full construction project only, and can be skipped if only scale models are being created. This assignment takes 1 to 4 days to complete.*

Install exterior wall coverings.

Unit 6: Rough In - Exponential & Logarithmic Functions/Sequences & Series

In this unit, elements are added to make the building fully functional. All mechanical systems, including plumbing, electrical, and HVAC are installed in the structure prior to completing exterior weatherproofing of the walls. The next step in this process is insulation, which encompasses thermal, moisture, and sound control. As students calculate the R-value for the insulation to ensure compliance with Title 24, they gain experience calculating with inverse variation as well as an appreciation of the many mathematical concepts that must come together in the building of a structure. Students continue to investigate the idea of mathematical modeling, specifically quadratics, as they design a water fountain or other landscape feature. The electrical component of this unit provides students the opportunity to work with sequences and series as well as complicated rational functions. Energy efficient HVAC systems are analyzed for cost/benefit analysis, a task lending itself to the study of exponential decay and requiring students to solve exponential and logarithmic equations.

1. **Circuitry Project and Worksheet:** *This assignment revisits and expands upon knowledge of linear and rational equations, and introduces the study of sequences and series. This can be expanded to a full study of sequences and series. It takes 1 to 2 days to complete.*

- Create parallel and serial electrical circuits using basic electric circuitry components (LEDs, SNAP grids, resistors, etc)
- Plot how different resistances affect the resulting output using an Ohm reader
- Solve problems given to them requiring them to find a specific component having a specific resistance in order to complete a circuit using rational equations to find the component in parallel circuitry (using the reciprocal of $1/R = 1/R_1 + 1/R_2 + \ldots + 1/R_n$), as well as using linear equations to find a component in serial circuitry
- Find the reciprocal of resistance given a series of resistances created mathematically on a grid ($1/R = 1/R_1 + 1/R_2 + \ldots + 1/R_n$)
- Find values of other sequences and series provided to them
- Write an explanation of their findings

2. **HVAC Data Graphs:** *This assignment introduces exponential growth and decay to students, which would be used as a springboard for the study of exponential and logarithmic functions and equations. It takes 1 to 2 days to complete.*

- Create graphs representing the amount of time taken to cool a space of a set size given an HVAC of a set BTU spec.
- Derive exponential decay formulas based on their graphs
- Create a write-up on which HVAC system should be ideally used for a space of a particular size

3. **Water Fountain:** *This assignment revisits parabolic equations, and provides a simple entrance into multiple physics-based Algebra 2-level word problems that tie together all topics covered thus far. It takes 1 to 2 days to complete.*

- Create a simple water fountain consisting of a water reservoir, closed pressurized supply system and electric pump
- Illustrate how plumbing works
- Document the results found
- Model the arc of the water fountain using a quadratic function to describe its maximum height as well as other information
- Explain in writing how this ties into fountain design
- Examine water pressure and find the water pressure of the fountain by measuring the diameter of the pipe, and the speed with which it fills a bucket
- Model this with various regression techniques on a calculator, and record the results
- Document how quickly various wells and their shapes will fill in an exploratory manner
- Document how three dimensional figures such as cones are filled using equations discovered by measuring the amount of water added given the cone shape

Unit 7: Finish Work - Complex Numbers

The project comes alive with the colors and textures that give it a unique personality and marketability. This unit represents the culmination of the work the students have completed throughout the course.[1] The structure itself comes together in this unit, starting with material selection, flooring, walls and roofing construction.[2] The project goal at the end of this unit is to have a completed structure and surrounding terrain. The students complete their investigation into the practical application of higher mathematics with an introduction into complex numbers and how they apply to electricity

Unit 7 - Assignments

1. **Drywall Installation:** *This assignment is meant for a full construction project only, and can be skipped if only scale models are being created. This assignment takes 1 to 4 days to complete.*

- Complete the procedure for installing and finishing of interior drywall system
- All Drywall is installed perpendicular to the framing. Assessment with Angle Square; must be exact
- All drywall is required to be installed with staggered joints; assessment by visual inspection
- All drywall is required to be installed with screws or drywall nails. These fasteners need to meet local building codes. Assessment by quizzes and visual inspection on construction site

2. **Finish Carpentry:** *This assignment is meant for a full construction project only, and can be skipped if only scale models are being created. This assignment takes 1 to 4 days to complete.*

- Specify the installation procedure
    - Interior doors including hardware
    - Cabinets and casework
    - Interior trim

3. **Electrical and Plumbing Finish and Trim:** *This assignment is meant for a full construction project only, and can be skipped if only scale models are being created. This assignment takes 1 to 4 days to complete.*

- Demonstrate proper installation
    - Receptacle and switch devices
    - Lighting fixtures
    - Plumbing valves and fixtures

2. **Surface finishes:** *This assignment is meant for a full construction project only, and can be skipped if only scale models are being created. This assignment takes 1 to 4 days to complete.*

- Evaluate options for finished covering
    - Wall covering
    - Counter tops
    - Floor covering

3. **Complex Numbers and Circuits Worksheet:** *This assignment covers complex numbers and their use in electronic applications. It takes 1 day to complete.*

- Investigate complex numbers and their application to electrical circuits
- Perform complex arithmetic as it pertains to the multiplication and addition of voltage and current represented as complex numbers
- Write a summary of their work with complex numbers as they relate to electricity

4. **Long Division Worksheet:** *This assignment requires long division, and completes student understanding of roots of functions. It takes 1 day to complete.*

- Calculate roots of polynomials through synthetic division and long division
- Compare and graph real roots, and find all roots algebraically (real and imaginary)
- Explain how the solutions to the division problems relate to the roots on the graph

Course Materials:

Title: Algebra 2
Edition: Current
Publication Date: 2008
Publisher: Holt McDougal
Author(s): Rinehart and Winston
Usage: Primary Text - Read in entirety or near entirety

Title: Modern Carpentry
Edition: Current
Publication Date: 2003
Publisher: Goodheart-Wilcox Company
Author(s): Willis H. Wagner and Howard B. Smith
Usage: Primary Text - Read in entirety or near entirety

Title: Architecture
Edition: Current
Publication Date: 2008
Publisher: Goodheart-Wilcox Company
Author(s): Clois E. Kicklighter, Ed. D.
Usage: Supplementary or Secondary Text

Title: Photovoltaic Systems
Edition: Current
Publication Date: 2010
Publisher: American Technical Publishers
Author(s): James P. Dunlop
Usage: Supplementary or Secondary Text

Title: Green Building: Principles and Practices in Residential Construction
Edition: 1st
Publication Date: 2012
Publisher: Delmar
Author(s): Carl Seville and Abe Kruger
Usage: Supplementary or Secondary Text

Supplemental Instructional Materials:

Unit 2: Organization(s):

1. Associated General Contractors of America (AGC) www.agc.org for materials, training publications and workshops. Instructors can access curriculum adopted by local construction apprentice programs using training techniques developed by AGC, including building materials and construction methods. In addition, practical application problems are presented and Construction Career Pathways are introduced.

2. Field trip to Architect and/or Engineers' office. This field trip provides students with the opportunity to observe Building and Construction Trades professionals at work as they create the design, draw the plans, and identify specifications for a project. Understanding the schedule and timeline for a project enables students to experience the remote coordination of a project from off site as well as become familiar with possibilities for the range of careers within the construction industry.

Unit 3: Videos:

1. Trade Demonstration on Foundations: Since most classroom projects can not include a full concrete pour as well as other building experiences, trade videos allow students to observe the phases in a build, such as the concrete foundation procedures from beginning (setting forms) to end (troweling a finish).
http://www.constructionbook.com/modern-foundations-1-video/trade-videos/

2. In this video, students observe the placement (pouring) of concrete as it applies to typical residential construction. Students benefit from the chance to see different concrete applications and placement methods used in construction industry as they make critical decisions about their own build.
http://livesteaua.com/view/JHj_BI2Fiqk/placing-our-footings/

Unit 4:

1. Framing: This video clip expands on the many techniques and options for framing in the construction industry. Even with hands-on activities and models, students may have limited opportunities to experience framing problems.
http://www.youtube.com/watch?v=92d_igiHbP0

The instructional use of this online video offers access to a wide range of methods and styles used in the industry. Students are able to see how framing materials and methods are influenced by region and design as well as observe professional framing practices that can be applied to their own projects.

Unit 5:

1. Exterior Enclosure: At this phase, instructors have the opportunity to show students many of the options in installation methods available for enclosing the exterior of the building beyond choices available for students' hands-on projects. This video clip provides the students with the chance to learn about "green building" cost benefit

options. Students can compare aesthetics of color, texture and lifetime cost analysis of roofing materials,exterior siding, and exterior windows and doors. They can problem-solve in order to match exterior finish materials with architectural styles and available design features. http://www.youtube.com/watch?v=iX245t_E4X

2. Field trip to a working job site. Students are introduced to real time work-site challenges as they visit the job site. All aspects of exterior finish or wrap can be related to the working environment. Students observe the skills, commitment, cooperation and safety required in the professional environment.

Unit 6:

1. Title: *Modern Residential Wiring* Harvey N. Holzman The Goodheart-Willcox Company, Inc. Tinley Park, Illinois 2002 This text provides a reference for layout and installation of the home electrical system. Units include designing with code, customer preference and consideration of client's aesthetic needs. The various tools, materials and equipment of the electrical trade are explained.

2. Title: *Workbook for Electricity and Basic Electrons,* Stephen R. Matt The Goodheart-Willcox Company, Inc. Tinley Park, Illinois 1989. The basic theory and fundamentals of electricity and electronics are introduced in this text. The text introduces industry terminology as it relates to practical application of electronics in construction. The book also presents basic methods for installation of residential wiring and photovoltaic systems using applied mathematics.

Unit 7:

1. Using Complex Numbers in Real Life: This provides access to an online website for student questions about the practical application of math, as it applies to the construction industry, and higher levels of formal mathematics disciplines http://www.math.toronto.edu/mathnet/questionCorner/complexinlife.html

2. "This Old House" Trim: This resource provides information for choosing and installing Finish Work items. Problems are presented and the "best solution option" is demonstrated. Segments about working with both old and new construction methods and materials are available.
http://www.thisoldhouse.com/toh/video/0,,20046338,00.html