

Creating a Cactus and Succulent STEM Garden

Developing and Utilizing Science, Technology, Engineering and Math Knowledge and Skills

Tucson Cactus and Succulent Society

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I. INTRODUCTION TO A STEM GARDEN



Creating a Cactus and Succulent **STEM** Garden is a project to help develop and utilize Science, Technology, Engineering and Math knowledge and skills in an outdoor plant environment. A small plot of land, about 12 feet by 12 feet or bigger, is desired for the site and becomes an environment to learn to care for plants and to provide monitoring, observing, studying and researching opportunities.

There are many steps involved in the creation and maintenance of the garden as outlined below and many opportunities for monitoring, studying, observing, experimenting and researching. Garden size, number and types of plants, complexity and associated activities can be scaled and integrated with classroom curriculum for all grades (K to 12). Many of the steps will require hands on experiences, some can be done in the classroom and others outdoors.

Each of the sections below can either be very simple to define and implement or more complex to utilize various knowledge and skills. Many Tucson area schools have developed “Demonstration” cactus gardens, that we are now calling STEM Gardens. Some applied for a TCSS Education School Grant to fund their project.

II. DEVELOPING A GARDEN CONCEPT AND WRITING A MISSION STATEMENT



It’s always good to do some brainstorming and ask students to contribute some ideas that can be written down (no discussion or criticism allowed at this point). The wilder the better to stimulate creativity. Another technique is to use sticky notes so each student can write an idea and then post them on a board for all to see. Also, the class could be divided into smaller groups with each group doing their own brainstorming and then bring the ideas back together to integrate together. Check out this type of a collaboration process by Googling on the word Charrette.

Once this exercise is completed it is time to discuss and build on ideas emphasizing that no idea listed is stupid or dumb. It is important to reach some consensus as to what the expectations would be if a STEM Garden was implemented. Why would we build one, how would it be used, who would use it, etc.

Creating a simple Mission Statement is important. Your mission statement should define what your garden is, why the garden is needed, what it generally consists of, what you want to accomplish and who will be the primary users once installed.

III. CREATING A GARDEN DESIGN



Once you have a concept outlined, it is time to create some details as to how you might be able to implement what you would like. Creating an artistic drawing will help you visualize how your garden will look, see Section XI-B for an example. You could do one drawing for the day the garden is completed and another one showing what it might be in five years after some growth. There are many items to consider in making a design. Some investigating will be necessary to understand what conditions, like temperature, shade, water needs, are necessary for your proposed plants. All cactus and other succulents do not require the same conditions. Here are some items for consideration:

A. Location

- Is the space available for the size of your planned garden?
- Is it too sunny or too shady? Does it change during the day and seasonally?
- Is it easy to get to, does it need some security access?
- Are there utilities under your area (water or gas lines, electrical wires, etc)?
- Is the ground too rocky, hard, hilly, sunken, will it flood and retain water etc.?
- Can you easily test your soil for amount of sand and clay mixture?

B. Plants

- Make a list of the types of plants, quantities and the sizes needed.
- Are the plants selected readily available and affordable?
- Do the plants need any special soil or cactus soil amendments?
- When picking locations for the plants, consider the artistic look and feel.
- How large will the plant will get in a couple of years?

C. Physical Considerations

- Do you need a path through the garden to access the plants, how wide if so?
- Do you want to outline the garden with stones or something else?
- Do you want the garden just be part of the existing landscape?
- Do you want to include a small sand area to capture animal footprints?
- Will you use plant ID signs? If so, what size, can your school make them?
- Be sure Safety considerations are listed, like no Cholla cactus next to the path where someone could brush against it or fall into it. Avoid tripping hazards.
- Do you have easy access to water? Will you harvest water? Will water cans be used?

D. Wildlife and Other

- Is the Garden being designed to attract wildlife? If so, what type of animals and how will you try to accomplish this?
- Are there some animals that you want to keep out of the garden? Why? If so, how will you accomplish this?
- Be sure and come back to this section to list other items you think of as you develop your garden plans.
- During your actual construction if you discover something was missed, add it to your Design document so it is complete and could be used by another class or school.

IV. DEVELOPING CONSTRUCTION DRAWINGS AND ESTIMATES



This is a fun part where you can apply math and analytical knowledge and skills. You will be doing many of the activities that an architect does when creating drawings to build a house or what a landscape architect does when planning and developing a landscape. You will also need to estimate costs and calculate quantities of materials needed. Here are some of the items for consideration:

A. Document Existing Garden Area

- What tools are needed to make measurements? Compass, level, tape measure, string, other? Do you have these or can you borrow them?
- Can you mark the garden shape and location on the ground using a stick or string?
- Can you measure the slope of the garden area and make a map to document it?
- If there are utilities under or near the garden area, document these on the map, ask school maintenance staff to help you and to review your map.
- Do you need to get a Blue Stake survey done (utility companies come out and mark on the ground with colored paint where their utility lines are buried, this is free)?

B. Plans and Calculations for the Garden Structure

- Do you need to add soil to level the garden or add a slope for drainage?
- Do you need to make berms for some of the plants?
- If soil is needed, what type and how much? Can you do the calculations? Where will it come from? What will it cost?
- If using rocks or other items for a border, can you calculate how much is needed?
- If you have planned a path, what material and calculate the quantity needed, where do you get it, calculate the cost?

C. Creating a Construction Drawing (see Section XI-C for an example)

- Get a large sheet of paper and a pencil (allow for many changes) to get started, draw the outline shape of the garden to scale or about to scale. A professional looking drawing can be created from this one once it is completed.
- Decide on symbols to use to designate types of plants (like Saguaro, Agave, Tree, etc), rocks, gravel, etc. Remember this is more of a schematic, not an artistic drawing like you already created from your Design section work. Do not use colors for symbols as they often do not copy well.
- Add your basic items first like the paths, berm shape outlines, planter walls or borders, etc.
- Then add symbols for any major items that have to go at a certain place, like a large Saguaro, etc.
- Place symbols for the larger plants at the designed design locations.
- Now fill in symbols for the smaller plants and any other items.
- Check your drawing against the plant list to be sure all have been placed.
- A good Construction Drawing should have the following: (acronym **DOGSTAILS**)
 - **D**ate the plan was created and also revision dates if needed
 - **O**rientation to show North, use an arrow on drawing, usually on top right
 - **G**rid to locate places on the drawing (optional but important on a map)

- Scale of the plans, distance (like 1 inch = 2 feet) use None if no scale is used.
- Title of the drawing and possibly a sub-title, include School name, address.
- Author for name of the person or persons who drew the plans
- Index to list any places on the drawing (optional but important on a map)
- Legend to list each symbol and then the meaning beside it.
- Sources to list where drawing information other than Authors was obtained.

D. Planning and Estimating the Work

- Can you make a list of the tasks that will be needed to build the garden? A good way to do this is to mentally visualize building the garden step by step.
- Can you identify items that can be worked on at the same time? Identify these to make the construction go faster.
- Can you create a simple flow chart to show the necessary progression paths and interdependencies? Advanced students can create a PERT (Project Evaluation Review Tool) chart, a formal project management tool used to schedule, organize and coordinate project tasks.
- Can you estimate the number of people and time required to complete each task?
- Do you need any special skills to complete the work? Do you have access to these or will you need to hire someone?
- Do the school maintenance people need to help with the project? If so, list what you need them to do to be sure there is no confusion or misunderstandings.
- What construction tools will be needed? Can the school or parents provide them? Purchasing them is probably a waste of money since they may be used only once.
- List tools for ongoing maintenance as these may need to be purchased or ask for donations.

V. PRESENTING YOUR PROJECT FOR APPROVAL AND SECURING FUNDS



Now that you have your construction drawings, estimates and many other details defined, you will probably need to get school approval. Your Teacher and Principal will know about this. It is best to develop and make a short and concise presentation so those who need to approve your project will understand what you want to do and why you want to do it. They will then be able to make an evaluation for approval. You may be asked to provide additional information or asked to change something if there are safety or other concerns.

You can start your presentation with your Mission Statement, then Design Plans (be sure to use graphics and sketches of your garden), a plant list, cost summary of major items (not details), where you may be able to get the money, tasks and time to build the garden, maintenance requirements, etc. Be sure to include all the names of students who worked on the project and your teacher and others who helped. This will give everyone credit and will also show the support that you have for your project.

If approved, you will then need to secure all the funds needed to do the complete project. You may need to do a fund raiser or apply for a grant so build this into your time schedule of your work plan. TCSS does award School grants to Teachers for worthy cactus and succulent

related projects so consider this a possibility. A printed copy of the Presentation that you made may be all that is required to apply for a TCSS Grant. If you can not get all the funds, some non-critical items may need to be dropped and maybe could be added at a later date.

VI. ACQUIRING PLANTS AND MATERIALS



This is another really fun part of the project. Individual students can be assigned to oversee this activity, to give out assignments, to check on the work completed and to make a list and check off the completed purchases. To get the proper plants and materials, use all the documents that were previously developed. Don't forget that you have an approved budget so you can not spend more for each item or group of items than allotted.

Several students can work on this at the same time by dividing up the list of items to purchase. Someone should keep a list of actual money spent on each item and keep a running total so everyone knows where they stand with the project cost. This will also give feedback to the students who did the estimates as to how accurate they were. You could even do a table or graph showing estimated and actual costs.

Don't forget to review the sequence and time schedule. You do not want to get plants too early if the dirt work or other items that must be completed prior to planting will take several weeks or even months. If you get your plants early, you will need to find a place to store and care for them.

VII. PLANTING THE GARDEN



This is an activity where the whole class and others who might want to volunteer can participate. With a lot of helpers and a coordinated effort the plants can all be all planted in a few hours. The plants can be numbered to correspond to the plant map and students can draw numbers to see what plant they get to plant. Little toothpick numbered flags can be placed in the dirt for proper locations. Do this with groups of 5 to 10 students at a time if everyone can't fit in the garden at the same time. Do the large plants first so the small ones do not get stepped or buried.

It is good to have a couple of cactus handling experts to advise on safe handling and good planting advice. They may be able to bring cactus gloves and planting tools, like tongs, spades, etc. Sometimes students taking photos of the plant and roots is helpful to document the condition of the plant as it goes into its new environment.

Some plants may need extra shade for several months. This would include Barrels and Saguaros and possibly some other plants. Shade cloth can be obtained from local nurseries and possibly TCSS.

VIII. DEVELOPING GARDEN MAINTENANCE AND CARE PROCEDURES



It is important to define what care, although hopefully very little for cactus and other succulents, will be required once the garden is planted and the time period this level of care will be required. Tucson basically has two seasons, winter and summer. Care lists should be prepared for each. Don't forget that the monsoon rains are an important factor to consider as well as possible winter freezes.

Maintenance items may include weeding, checking on signs, cleaning up any trash, cleaning the path, straightening rocks, etc. A plan for summer months when students are on vacation may need to be developed depending on the plants and conditions in the garden.

This is a great opportunity to develop a chart of responsibilities and tasks to be performed. You may also want to consider a chart or method to document the health or problems observed about certain plants or overall garden problems.

IX. OBSERVING AND STUDYING



Hopefully the garden will have a variety of cactus and other succulents as well as a few other native plants. The variety provides many opportunities to observe and study several plants that are being exposed to the same conditions.

Also, there will be more going on in the garden than just the plants and their interactions. Many insects, birds and other animals will undoubtedly visit or take up residence in the garden. Listed below are some ideas:

A. Observing

- **Buds** - Note when buds start to form and flowering dates, when they open, close, do they reopen the following day. When do new stems start growing?
- **Animals** - Record what animals are visiting your garden. Can you hear them, see them, smell them, find their scat, see footprints, find nibbled flowers and fruit. Keep a class journal with this information and see how much of it repeats from year to year.
- **Tracks** - Consider placing a small area in the garden of fine sand that is smoother to capture animal footprints or other marks. Check it every morning and keep a log.

B. Studying

- **Temperatures** - Measure and record temperatures (plant, soil, air) and rain amounts (did you install a rain gauge?). Should you measure at pre-defined times or intervals. Make charts.
- **Growth** - Measure and record and/or photograph plant shape, size, and other characteristics like spine length, colors, etc. How do the shapes and colors change over time, why?

X. CONDUCTING GARDEN EXPERIMENTS AND RESEARCH PROJECTS



The garden can be used as an outdoor laboratory to conduct experiments. This may be useful as a science project, possibly a class science project. Do a cactus related brainstorming session in the classroom with statements starting “I wonder why ... Or I wonder if... “. Just write them down without discussing or allowing any criticizing. Use later for discussion topics and build on them or add ongoing thoughts. When conducting Experiments and Research keep all your senses and brain wide open for Discovery! Keep good notes. A few ideas are listed below:

- A. Nectar** - Ants often visit Barrel cactus for sweets, a type of nectar. Can you find something they prefer over the Barrel cactus nectar. When do they visit, how often, is it the same ants, what type of ants. Can you analyze the Barrel nectar fluid.
- B. Growth Rates** - How does the temperature of a cactus affect its growth rate. Is the surface temperature a good measure to calculate the internal temperature.
- C. Cochineal** - How can you expedite the growth of cochineal on Prickly Pear cactus. Is it the same quality as normal growth rate cochineal. What is the density of the cochineal.
- D. CAM** - What can you discover about the CAM photosynthesis process that most succulents use. Can you measure it, if so, how efficient is it to regular plant photosynthesis. Can you alter the process to the betterment of the plant.
- E. Protection** - What techniques could I develop to protect special plants in the garden or the whole garden from insects and other animals.
- F. other?**

XI. SUGGESTED ITEMS AND DRAWINGS

A. Suggested Items to Construct, Monitor and conduct STEM Garden Experiments

Special items for activities above, need one each per garden project:

- 1) String bubble level to measure before and after garden terrain (\$3)
- 2) Small roll of mason twine to layout garden area and to use with bubble level (\$3)
- 3) Hand held IR laser temperature gun to measure surface temperatures for monitoring, experimenting and research (\$15 on ebay.com)
- 4) Plastic cylinder rain gauge, stick in the ground type (\$4)

Other items needed that are commonly available:

- 1) Paper, clipboards, color pencils, ruler, tape measure
- 2) Garden tools, shovel, rake (borrow from school or parents if you need to)
- 3) Garden hose and/or watering can
- 4) Computer for storage and analysis of data collected and for creating a presentation

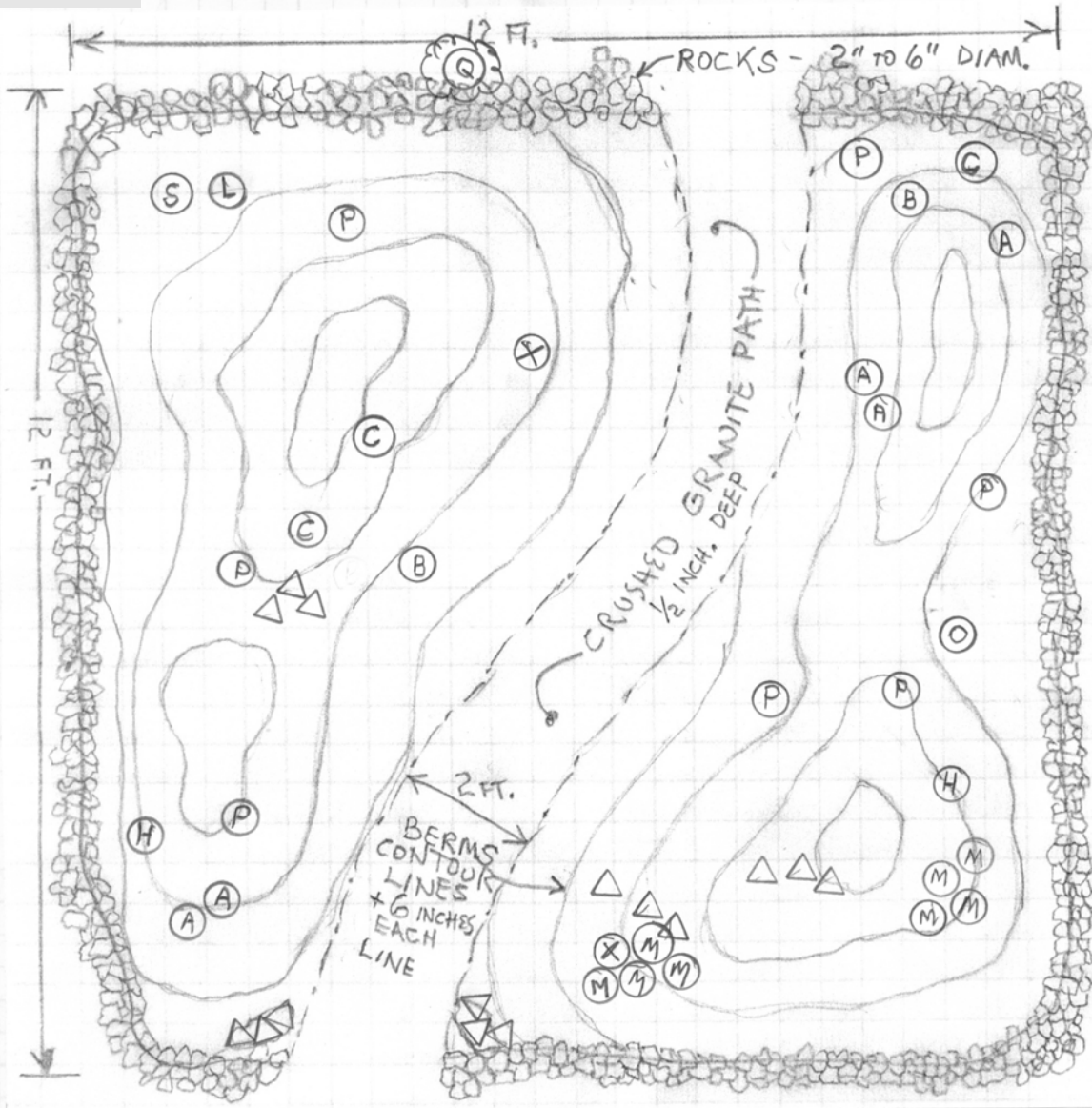
B. Artistic Drawing of Proposed Cactus and Succulent STEM Garden



C. Construction Drawing of Proposed Cactus and Succulent STEM Garden

XI. C. CONSTRUCTION DRAWING

↑ NORTH - ↗ MAIN OFFICE



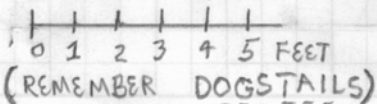
LEGEND

(A) PLANT TYPES

- A = AGAVE B = BARREL C = CHOLLA
- H = HEDGE HOG M = MAMMILLARIA
- O = OCOTILLO P = PRICKLY PEAR
- Q = QUEEN OF THE NIGHT S = SINGUARO

- △ = LARGE ROCKS X = BUSH-NATIVE
- ⊙ = TREE-EXISTING L = LIMBER BUSH

SCALE: 1/4 INCH = 1 FT. 0 INCHES



← AGAVE GARDEN ↗ HOOP HOUSE

PIMA PRICKLY PARK -
CACTUS STEM GARDEN

3500 W. RIVER RD., TUCSON, AZ 85741

DATE: 5/24/15
DRAWN BY: JOE FRANNEA

MY COMPANY OR ORGANIZATION:
TUCSON CACTUS & SUCCULENT SOCIETY

REVISION No. 1 SHEET NO. 1 of 1