DARPA ENGAGE Project
Team Illuminate
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This is an initial proposal for the educational approach of our tower- and structure-building game, intended to communicate ideas and foster discussion regarding these four areas:

1. Tiers of Learning
2. Game Modes
3. Center of Mass
4. Collaboration

Tiers of Learning

This is our suggestion for the chronological order in which certain concepts might be taught within the game. We've divided this into tiers so that Tier 1 would be the very first levels and Tier 7 the very last. The concepts were chosen based on the engineering principles sent to us and our past discussions with representatives from HCII.
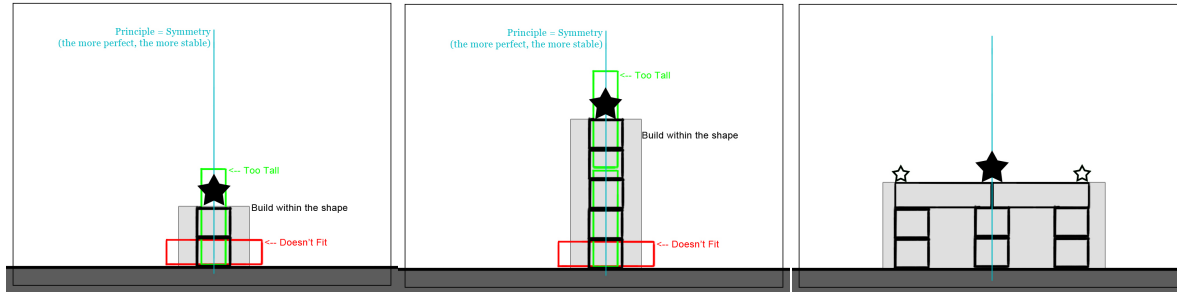
Each principle is intended to create a more stable structure. While there are other factors an engineer might consider besides stability--such as efficient use of materials, a small footprint for the building, and the building's overall aesthetics--we have focused only on stability for the concept tiers described below. (True, the game may have a finite inventory of blocks for each level, which does touch on efficient use of materials, but that's the only exception.) This emphasis on stability also matches the engineering principles that HCII provided us, which also do not address those additional factors.

To be clear, we may not be able effectively teach all of these in the amount of development time we have. Therefore we would like feedback on:
- which principles seem most beneficial to teach
- the order in which we should teach these principles
- other principles we may have missed
- challenges we may face in teaching certain principles

NOTE: The images under each tier are examples and do not represent the final level progression that will instill each principle. Each tier is likely to have far more levels, and more gradual levels, than are depicted.
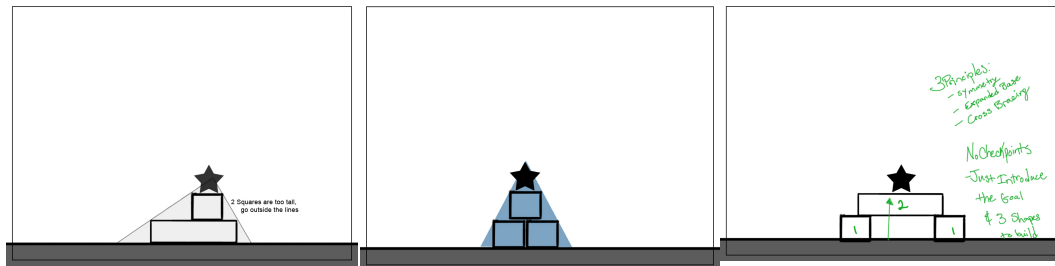
Tier 1 - Symmetry

Principle = Symmetry
(the more perfect, the more stable)

<-- Too Tall

Build within the shape

<-- Doesn't Fit

Principle = Symmetry
(the more perfect, the more stable)

<-- Too Tall

Build within the shape

<-- Doesn't Fit

Summary of the principle - Things that are aligned and have equal distribution of weight tend to be more stable.
How the level design will foster it - Guided, build within the outlined gray shapes
Benefiting modes - Earthquake, goal, remove a block(?) -- (*See the 'Game Modes' section for an explanation of each possible mode*)

Tier 2 - Wider base

.2 Squares are too tall, go outside the lines

3 Principles:
- Symmetry
- Expanded Base
- Cross Bracing

No Checkpoints
-Just Introduce the Goal
& 3 Shapes to build

Summary of the principle - Things built more in the shape of a pyramid or a triangle tend to be more stable, so that when the upper pieces shift, they have room to do so.
How the level design will foster it - Guided, build within the outlined gray shapes
Benefiting modes - Earthquake, goal, remove a block.

Tier 3
## Heavier objects on the bottom (lower center of mass)
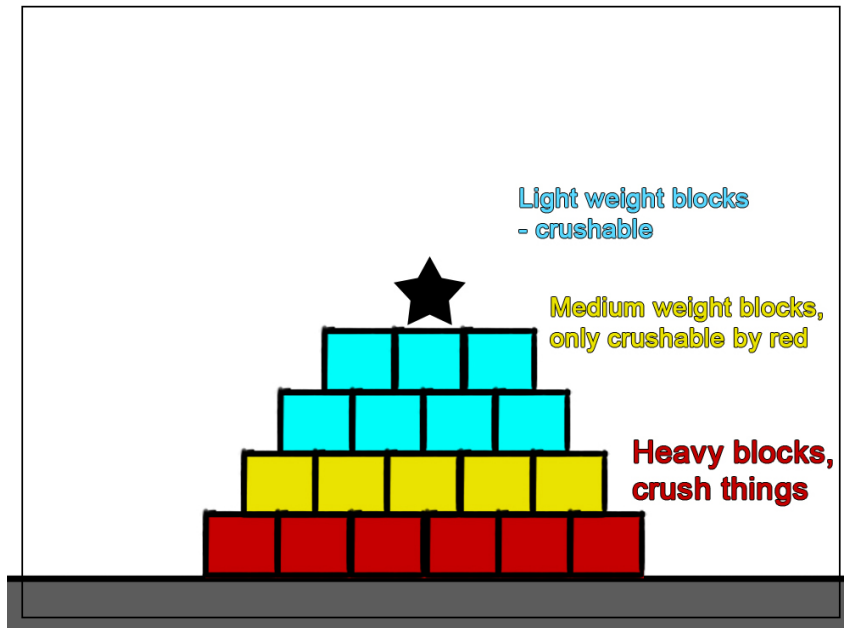
Summary of the principle - Heavier weights lower the center of mass, keeping the objects stabilized on the ground

How the level design will foster it - Certain blocks would need to be different shapes, colors or textures that were established by the game as indicators of weight. For this example, we've used color, and it would have to be assumed that red is heavier than yellow is heavier than blue.

Questions we have or challenges we foresee - Weight may not be as important or teachable a concept in a virtual game as it is with real blocks that you can hold in your hand. For simplicity's sake, different weights probably should also be reduced to a simple dichotomy (heavy-light) or trichotomy (heavy-medium-light).

Benefiting modes - Earthquake, goal, remove a block (?), freeform (?)

Tier 4 - Closed gaps
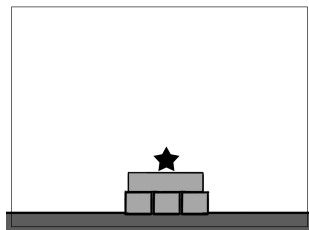
Summary of the principle - Constructions built with a more solid bottom (that expands the length of the building) tend to keep the building more stable.

How the level design will foster it - (?)

Questions we have or challenges we foresee - Children with two square blocks under a wide beam (see the third picture under Tier 2) might consider it more important to close the gap than to have a wide base, and so might push the square blocks into the center, creating a less stable structure.

Benefiting modes - Earthquake, goal, remove a block, freeform
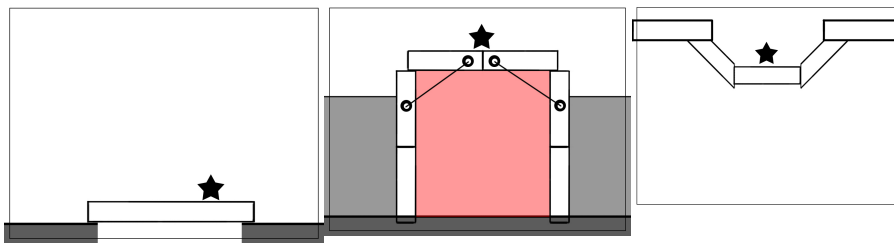
Tier 5 - Buttresses
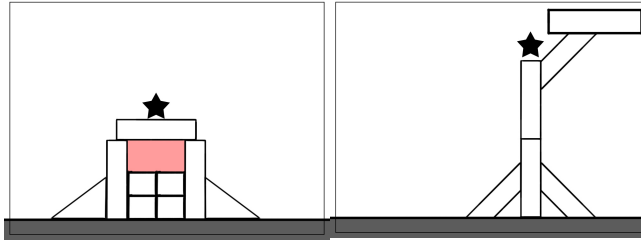
Summary of the principle - Buttresses attempt to stop buildings from swaying or moving, and hold them into place.
How the level design will foster it - Limited pieces that aren't stable will need to be braced.
Benefiting modes - Earthquake, goal, remove a block, freeform (?)

Tier 6 - Struts - Bridges

Summary of the principle - Some construction involves buildings, and therefore learning how to bridge a gap is important. Doing this with struts could also evolve into how roofs are made.
How the level design will foster it - The goal is suspended above a gap so that building straight up won't allow the player to achieve the goal.
Benefiting modes - Earthquake, goal, remove a block (?), freeform (?)

Tier 7 - Cross-bracing
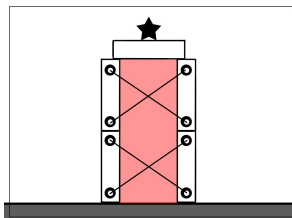
Summary of the principle - Cross-bracing stabilizes the building against torque (i.e. from side-winds or earthquakes) by connecting sections of the building in an X shape.
How the level design will foster it - Limited pieces that aren't stable on their own.
Benefiting modes - Earthquake, goal, remove a block (?), freeform (?)

Game Modes

In addition to having a progression of levels, it may make sense for the game to have different modes. These can't be major variations on the core mechanic, but we can have modes like:
- **Earthquake** - Build a structure that can survive an earthquake
- **Goal** - Reach or support an object at a specific point that serves as the goal (as our current level designs do with the star block)
- **Remove a block** - Remove a block or multiple blocks from an existing structure and see if that makes it more or less stable
- **Freeform** - Allow children to experiment with the blocks within the physics engine without any constraints or goal

Modes could vary naturally from level to level, or could be selectable from a main menu. (Freeform would certainly be a main-menu-selected mode.)

While previous discussions have often assumed that these would all be part of a single mode of play (i.e. a game that simultaneously has a goal *and* expects your structure to survive an earthquake, within the same level), we feel this is creating a conflict of objectives and it might be better to separate these objectives into separate modes.

If we do go in this direction, we will have to do careful prioritization of the modes that will provide the richest learning experience, while still resting on the same core mechanics and fitting within our scope. If we develop the game with more levels, for example, in order to get a more gradual progression of concepts, that means less development time that we have to dedicate to different modes, and vice versa.

Center of Mass

We have three options as regards center of mass:
1. Ignore it completely and rely on related concepts (such as keeping heavier objects on the bottom) that are more accessible to first graders
2. Show the white dot (joint center of mass of all objects onscreen) or some other visual cue, but without explicitly teaching center of mass. We may be able to adjust the visual cue to be more relevant (i.e. figure out how to make the joint center of mass only count objects that are part of the tower) or more intuitive (change the white dot to a "balance needle" that tips left or right). If so, the need to explicitly teach center of mass may be reduced.
3. Explicitly teach center of mass. If we do this, it would probably need to be done around the time of Tier 3 in terms of the chronological progression of the levels, or in a different mode. However, it could be argued that teaching this concept explicitly is bordering on a different game entirely. Center of mass could also be taught by the school teacher in a lesson plan meant to augment the game.

Collaboration

Since collaboration is not really a science concept, but just a reinforcement tool for learning, collaborative levels will either have to be handled as a different mode, or as an interlude between tiers.

Rather than have a progression like--
      Tier 1 single player
      Tier 1 collaborative
      Tier 2 single player
      Tier 2 collaborative
      ...and so on
--it makes sense to us to introduce a set of a few concepts as a single player experience and only then apply them jointly in a collaborative experience.

This progression would look like
Tier 1 single player
Tier 2 single player
Tier 3 single player
Tier 1,2,3 collaborative
Tier 4 single player
Tier 5 single player
Tier 4,5 single player
… and so on

If we have a separate collaborative mode, this would basically work the same way, except that control over when the collaborative levels occur would come from the main menu, rather than from a strict linear progression of levels.