Worldly Wise

Problem Solving with Scientific and Logical Inquiry

- by -

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Project Proposal

CSE 494 (598) Design for Learning in Virtual Worlds (Spring 2014)

Contents

1 Statement of Instructional Problem and Proposed Solution....1
Stemming the bleed....1
Level me up....1
I think, therefore I am....2
2 Rationale for a Virtual World....3
Concern: There's a disconnect with the real world....3
Benefit: Performance can be monitored....3
Benefit: Virtual world is a laboratory....3
Concern: Where is the time?....3
3 Target Audience and Instructional Setting....4
4 Learning Objectives....5
Scenario: Fixing the raft....5
Scenario: Light up the way....5
Scenario: The rainbow effect....5
5 Description of Treatment....6
Interaction....6
Perspective....6
6 Content Outline....7
7 Program Flow....8
8 Proposed Time Line....9
9 Proposed Budget....9

1 Statement of Instructional Problem and Proposed Solution

The last few years has seen a lot of focus on education in the fields of (physical) sciences, technology, engineering, and mathematics; often abbreviated as *STEM*. While acknowledging the role of STEM fields in overall economic development, the focus has brought to fore a debate about the effectiveness of current teaching (and learning) methodologies.

Stemming the bleed

The United States Department of Education reports[1] that growth in jobs over the next few years will primarily be in the areas related to STEM fields and, as such, newer education policies must address this. Further, the same report suggests that only 16 percent of all American high school graduates are proficient in mathematics, and the statistical trend is unfavorable.

From experience as an educator we find agreement with this assessment – indeed, many students at the University are found lacking in all STEM fields, but mathematics more so. At the core the issue not of material – the fundamental ideas of trigonometry, Newton's laws, etc. are covered. Rather, it is felt that students are not exposed to application of these concepts to a broader set of problems.

There is also a belief that students learn differently and at different speeds. That traditional learning, with its rigid structure, is not meant for everyone. With access to technology burgeoning, the recent years have seen increasing attempts at providing different tools to facilitate learning, both inside and outside the classroom.

Level me up

In this project we aim to develop a tool to facilitate learning in the STEM fields. The focus is to create something that can complement classroom education and strengthen a students' understanding of certain concepts; indeed, we do not think this will be a good replacement for the teacher. A majority of the people are already introduced to video games and, therefore, a tool like this will not feel out-of-place for them.

A game is like any other application – it goes through similar development processes, has the same constraints and, often, suffers from the same problems. The one thing that distinguishes a game is that it is fun to play. Students who find the classroom experience overbearing and boring will invariably find edutainment tools useful to fill the void.

Another argument in favor of using games for education is the new-age concept of achievements. Every player realizes that such achievements are desirable and so, as developers, there is an opportunity to guide the player performance by offering different achievement levels. At the same time achievements are qualitative and does not lead to ready comparison. So, the issue of leader boards (peer pressure) is ameliorated to some extent.

1 http://www.ed.gov/stem, retrieved 14-Feb-2014

I think, therefore I am

The proposed project will make use of a virtual world framework. The player will be in a different world with some problem(s) that need solving. The process of solving would involve *learning* new concepts in the game and then *applying* them to solve the problem the problem at hand. A student who already knows the concept will still need to do certain steps as proof – in effect reinforcing the concept through practice.

STEM fields are ideal for such games. Several concepts can be easily visualized, and the experiment to do so can be easily constructed. The best example in this regard is Archimedes' principle for volume displacement. An hypothetical problem in the game will require the player to calculate an appropriate volume of metal or to calculate its density.

Mathematical problems are also possible, but perhaps difficult to engineer for visual understanding. Problems from the realm of probability, logic, arithmetics, and geometry are all viable areas, and problems may be based in conjunction with some other concept.

2 Rationale for a Virtual World

There are different arguments for and against the use of virtual worlds in traditional domains. In this section we try to address a few and discuss how those play a role in the project at hand.

Concern: There's a disconnect with the real world

In this age of easy information and social media too often students are in the classroom only in flesh. In recent years, there has been a systematic increase in regulating students' use of technology in the classroom. At first glance, our proposal seems to ignore this concern. However, we reiterate that our tool is not a tutor – there will be parts of the concept embedded into the virtual world and other hints as well, but it is expected that the student is introduced to the concepts. This also leads to the next point.

Benefit: Performance can be monitored

Too often, students are not active participants in the classroom. In our experience, calls for volunteers for in-class activities generally provide the same hands. When playing games, a student can be more at ease and, one can expect, that the shy ones will more readily "explore" the world. In theory, anything and everything done in the game can be logged, but with smart filtering such information can be used by instructors to make a qualitative assessment of the students' progress. Even something like in-game achievements can be a great indicator.

Benefit: Virtual world is a laboratory

For many concepts in the physical sciences, the proof lies in construction of the problem. In some cases such construction can prove expensive and be prone to failures. At other times such construction is simply not possible, or is too dangerous to be exposed to students. All of these are problems not inherent in a virtual world. A student could get electrocuted, handle sodium, and perform space travel, all in a day's ~~work~~ play.

Space travel and associated concepts are very interesting in a virtual world. Ideas such as variable gravity, lightning-fast travel, etc. are perhaps not possible in a regular laboratory. Also, such fantastical ideas like magic are possible, although beyond the scope of our project.

Concern: Where is the time?

Many kids (and adults) are already spending too much time in virtual worlds and games. Not only do we have finite amount of time, do we really want to encourage more time spent on devices? To at least address this concern, our game has no concept of high-score. Sure, you can perform the experiments again, but there is no exalted level of bragging rights for playing longer. The game may log the hours spent (more hours but without achievements can be an indicator for failure) but will not provide quantitative results.

3 Target Audience and Instructional Setting

The audience for this game can most readily be identified as teenagers and young adults. From the way the idea has developed, we no longer believe the end result will benefit middle schoolers or younger children. Part of this belief is also due to our lack of knowledge about the current school curricula. The problems can easily be made more complex and thus suitable for freshmen at the University level who will find such games challenging as well as good review.

In any case, we are not targeting the mature audience: so, there will be no use of obviously fantastical ideas (magic, zombies) or sex or gore. The topic at hand is one of learning scientific concepts, and it is perfectly possible to do this in a fun way without having to pander to popular demand.

The working title of this project was *Problem Solving with Scientific and Logical Inquiry*, and that pretty much sums up the instructional setting for the game. As is described in a later section, this will be an adventure-oriented game with factual elements in the mix. When, it comes to using an apparatus, it feels that a first person view is better. However, there is no reason why a third person perspective should be discounted. Most interactions are mouse based, and the perspective makes no difference whatsoever.

The game will built into separate sections, each with a set of puzzles that are linked. In addition, a central laboratory can be the place where you return to perform experiments and get more knowledge. In a way, it resembles the average student's life as well, with the laboratory here representing the school and/or home. Although there are restrictions on where you can go in the game (doors are closed, or bridges broken, etc.) the over-arching theme is one of unsupervised learning.

The instructional setting is *informal*, and there is really no definition to who you are or are not. Doing badly will not adversely effect you, however puzzles once gone bad will mean the player has to redo it all over again. So, as the puzzle progresses, the stakes get *higher*. The mode of instruction is *unguided*, but frequent hints and feedbacks can guide the attentive player. If this game was used in a course, the ideal application would be as some *self-selected* extra credit component, or something in lieu of assignments. The game can become long if the solutions do not come forthright. In some cases, the in-game schematic may require off-game analysis as well. The game itself is not timed.

4 Learning Objectives

The major goal of the game is to introduce students to higher level thinking. We achieve this through minor goals that enhance the understanding of certain concepts by the player. There are several such concepts that have been identified:

1. Archimedes' principle for displacement of volume
2. Newton's laws of motion and the classical mechanics equations
3. Ohm's law and constructing resistances in series / parallel
4. Pythagoras' theorem and other geometry concepts such as area and volume
5. Algebraic ideas like solving for unknown variables
6. Snell's law for refraction

Each idea might lead to one or more puzzles. Currently, the focus is on items (1) and (3), which seem easier to develop. A successful completion is determined by finishing the puzzle. To illustrate this, some sample scenarios are as follows:

Scenario: Fixing the raft

You needs to cross the river, and all you have is the river raft, which can be inflated. There is a pump nearby, which can be used (how about the Power Cell puzzle here?) but the raft deflates immediately after the pump is turned off. You need to replace the ball-bearing mechanism used in the raft. Back at the laboratory, you have a mold and furnace to create the ball, but need to compute the appropriate volume.

Scenario: Light up the way

You are at a point where something needs to be done on a control panel, but you can't see anything. You realize the problem: the bulb is blown out. You can replace the bulb, but you will also need to supply the appropriate voltage for it to work. A control board outside provides constant current, and you need to build the circuit with resistors (in series and parallel) so that the appropriate voltage is provided to the bulb.

Scenario: The rainbow effect

The security device can only be disabled if both the lasers cast the same frequency. One of them is fixed, but you can change the other one. But to what frequency, and why does that prism cast a rainbow? To solve this puzzle, you will need to use the prism device on the fixed laser and compute the frequency of the light.

5 Description of Treatment

The game will take the adventure-oriented with liberal addition of factual concepts. The focus is not so much of raw knowledge but rather on the ability to apply concepts to solve existing situations in the game.

The fundamental concepts of an adventure game apply. The player will need to explore and perform tasks to progress through. The exploration aspect can be exploited to nurture other skills as well – reading, visual analysis, as well as auditory interpretation. To keep the scope limited, however, we will concentrate only on written and other (non-verbal) visual cues. Audio may be used for ambiance and for providing feedback.

Interaction

Interaction will prove pivotal to the success of such a tool. There is no point giving a needle-in-the-haystack situation; instead the player will be provided appropriate feedback when they *find* interactive elements (for example, the cursor changes when the mouse hovers over a key) or other hints (textual) when they are lost. Interactivity can be provided through the mouse with the drag-and-drop method showing the most promise.

On successfully completing a puzzle (or a part thereof) an appropriate feedback will be provided. An audio feedback (like clapping sound) seems nice, although visual feedback through animation is also possible.

Perspective

As mentioned earlier, both the first-person and third-person perspectives are possible for working in such a 3D virtual world. We are currently leaning towards a first-person view simply because it appears easier to control and provides a more wholesome look. From a programmatic perspective, there is no inclination to do "action" animations except for the basic ones of locomotion, that too in the third person mode.

A useful addition will be that of expanded hints, when the player seems clueless about something in the game. This can be implemented automatically (after detecting that the player has failed at the same level many time, like *Chip's Challenge*) or controlled manually by the instructor. This can be an added feature, but is not a part of the current design.

6 Content Outline

The product will primarily depend on programming efforts with limited input from 3D modeling. Some 2D painting is expected to provide textures for schematics in the game. Animations employed will be simple affine transform based (so, no skinning) and should be within the scope. Much of the time will be spent in getting interactive elements to function.

1. Models
   - Archimedes: inflated, deflated raft, pump, beaker, iron shavings
   - Ohm: switch board, resistor, bulb
   - Rainbow: prism, laser beam machines
   - Laboratory: tables, books, etc.
   - Terrain(s) for the different regions
2. Textures
   - Schematic for most concepts (hand-drawn, then scanned, then improved)
   - Worldly textures like wood, dirt etc. for the different objects
   - GUI textures for the skin (any interactive interface will mostly be 3D)
3. Sounds
   - Music
   - Sounds for basic actions (locomotion), as well as interactions
4. Functionalities
   - Drag-and-drop 3D objects
   - An inventory system, if needed
   - Reviewing concepts (read learned concepts anytime)
   - Lots of trigger actions

7 Program Flow

From a Unity perspective, the program flow can be easily controlled through the use of *scenes*. The following schedule includes such demarcation, while also indicating where and what the player will experience.

1. Main Menu
   - Access to other parts of the game, as also the controls and credits
2. Tutorial
   - Can be skipped
   - Basic introduction to the drag-and-drop interface. Simple problem, and solving it with step by step instructions.
   - Define other things in the game as necessary (inventory, is available)
3. Game (multiple scenes may be used as necessary)
   - Game starts near the first puzzle. A quick tryout indicates the problem. Either indicate outright the location of the laboratory, or allow the user to explore
   - The laboratory located centrally. Bunch of tables and other accessories. Can only use tools that are applicable in the current scenario (to avoid the needle-in-the-haystack problem). Schematics or other information about different concepts
   - Audio-visual feedback on most actions, but the important ones indicated through louder or longer sounds or cut-scene style lock on the camera while an animation unfolds
   - No true end condition, once the basic flow is completed, the player is heralded as master of the world, and continues to live along
4. Achievements
   - Total amount of time played
   - Puzzles “unlocked”, relevant concepts learned

8 Proposed Time Line

The development scope of this project is limited, in time, to the current semester. Keeping this constraint in mind, the following table enumerates the tasks into different categories

	Particular	Status	Target
Design	Brainstorming Ideas	Completed	17-Jan-2014
	Preliminary puzzles	Completed	31-Jan-2014
	Proposal Report	Completed	14-Feb-2014
	Identify puzzle assets		28-Feb-2014
Build	User Interface (also GUI)	In Progress	07-Mar-2014
	Building the assets in game (prefabs)		14-Mar-2014
	Triggers and interactions		21-Mar-2014
	Feedback – sounds and visuals		28-Mar-2014
	Design Document / Alpha Testing		04-Apr-2014
Refine	Adding achievements system		11-Apr-2014
	Hinting system for failing		18-Apr-2014
	Testing results		25-Apr-2014
	Final Report		02-May-2014

9 Proposed Budget

Budgetary allocation for this project should be as under. We have proposed a slightly more conservative approach, keeping in mind the tight schedule

	Particular	Level	Cost (USD)
solTo	3D Modeling Tool	Hire	200
	Pen Tablet and software	Buy	500
	Unity (for multiple platforms	Hire	1000
	Deployment (website, etc.)	Buy	100
People	Full-time Staff	Hire	15000
	Testing	Payout	200
	Web design	Hire	1000
	Advertising	Hire	500