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Web Based Virtual Environment For Education - S'cape

by

Atul Thapliyal

A report submitted in partial fulfillment
of the requirements for the degree
of

MASTER OF SCIENCE

in

Computer Science

Approved:

Dr. Nicholas Flann	Dr. Curtis Dyreson	Dr. Dan Watson
Major Professor	Committee Member	Committee Member

UTAH STATE UNIVERSITY
Logan, Utah

2012

ABSTRACT

Web based virtual environment for education

by

Atul Thapliyal, Master of Science
Utah State University, 2012

Major Professor: Dr. Nicholas Flann
Department: Computer Science

Simulations provide an environment to experiment safely, openly, and repeatedly for learning mastery. However, many simulation environments experienced within a classroom fail to include automated assessment components or automated data collection. Even when assessments are included, often they fail to account for the unpredictable nature of decision-making within a complex, 3D, open-ended simulation environment. Embedding assessments within a virtual simulation environment poses several challenges. First, the program must provide assessments aligned with educational requirements that will not take the learner cognitively "away" from their activities. Second, the program must not detract from the game-like experience that learners find engaging. Third, assessments should maximize the benefit of the unique capability of digital deliveries, including the ability to allow for the geographically disparate and asynchronous schedules of instructors and learners. This report addresses each of the above challenges in the context of an implementation of a simulation in a classroom environment. The simulation described in this report is designed to function as a stand-alone module to teach and evaluate core concepts of a K-12 curriculum.

ACKNOWLEDGEMENTS

First, I would like to thank Utah State University, Computer Science department for providing me with an opportunity to pursue my Master's Degree. I am grateful to Dr. Nicholas Flann for his support throughout my graduate career and during the course of this project.

I would like to thank Dr. Curtis Dyreson and Dr. Dan Watson for their input and interest in this report. I am grateful to Dr. Brett Shelton for supporting and guiding me throughout this project. His domain knowledge of instructional technology and his clear vision were vital for the success of this project.

Last but not least, I would like to thank Anuj, Ashish, and my parents for their support and encouragement in all my educational pursuits.

Atul Thapliyal

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CHAPTER 1 INTRODUCTION

This project was developed as a part of National Science Foundation Discovery Research K-12 Grant (NSF 09-602). Research and development of interactive simulation systems for use in traditional education is an area of active and increasing interest. However, assessing student learning in a 3D environment has been a challenge for educators. This project is focused on designing an educational 3D simulation with embedded assessment and data collection.

This project also provides a space for safe experimentation by students, which has been a major concern in school laboratories. Students are assisted during the assessment by the replay feature which they can use to review their actions in the 3D environment. While the 3D environment provides students with opportunities and innovative ways to improve learning, determining the effectiveness of this new approach depends on how the assessment is designed. Even though it is difficult to design assessments which offer high adaptability in a 3D environment, the combination of strategies like data and task tracking, offer the potential to create effective embedded assignments. This project reports a study involving S'cape, a 3D educational simulation for middle-school science that includes automated assessment and automated data collection. In S'cape, players navigate through a virtual alien environment, attempting to escape from their alien captors by performing experiments.

Eighth grade science teachers from across the Western U.S. were brought together in a focus group environment to discuss desired aspects to be covered by a simulation environment, as well as the type, style, and functionality of the embedded assessment. A

prototype version of S'cape was then used by high school students in two of the teacher's classes in order to pilot test the simulation environment and the embedded assessment. The teachers themselves, in connection with the university, were considered the subject matter experts (SMEs) and advisors in creating the assessments and ensuring adequate levels of complexity in the nature of the simulated environments.

CHAPTER 2 GAME OVERVIEW

This game is designed from a first-person shooter (FPS) game perspective (i.e., the student/player is directly seeing and interacting with the environment) to teach *Utah state science standard one, objective one* from the core standards.

- This game and standard is arranged to teach eighth grade students the nature of changes in matter
- This computer based interactive environment, in connection with classroom instruction, will cover the components of standard one of the eighth grade core

The game is playable through a web browser on any computer with Internet connectivity. The student/player begins by finding themselves in a single room with a single locked door. The player, through narration, learns that he or she has been abducted by aliens that are experimenting on them in order to observe the problem solving capabilities of humans. The student/player must solve a series of tasks designed to help them learn about the properties of water in order to open the door and escape. Within the environment there are hotspots that the player can click on to bring up a molecular view within a globe showing what is happening at the molecular level.

In the first level of the game, the student/player wakes up in a room filled with various elements with which they can work. The student/player must determine how to create ice, water, and steam from elements in the room. Accomplishing these tasks allows them to open the door and escape. The screen capture in Figure 1 shows what the environment looks like :



Figure 1. S'cape Environment

Students interacts with this environment in a first person shooter style game. Within the environment are various hotspots(e.g. blue basin of water and hood above it) that students can examine and interact with. When students click on the red button, they will see the following two changes. First, the blue basin of water has begun to boil and there are particles(vapors) rising into the hood as shown in Figure 2:

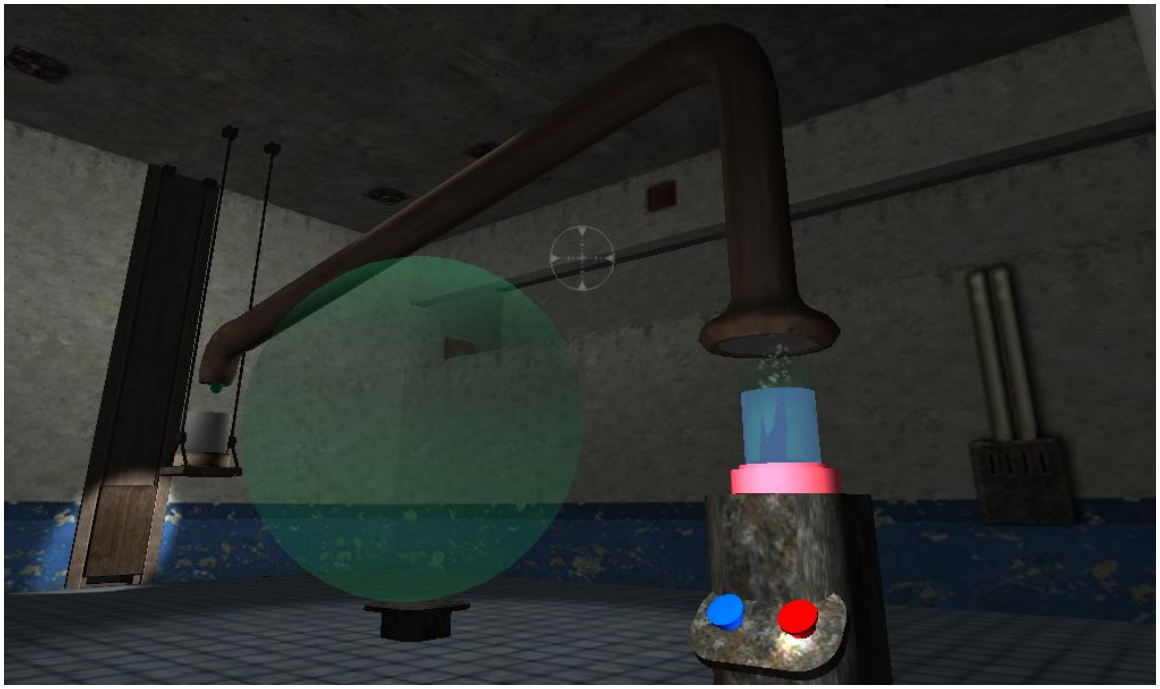


Figure 2. Heating of water

Second, students will see the droplets (condensed water vapor) falling into the bucket which is connected to one end of a pulley system, and that this process is slowly raising the door which is connected to another end of the pulley system, in the wall as shown in Figure 3:

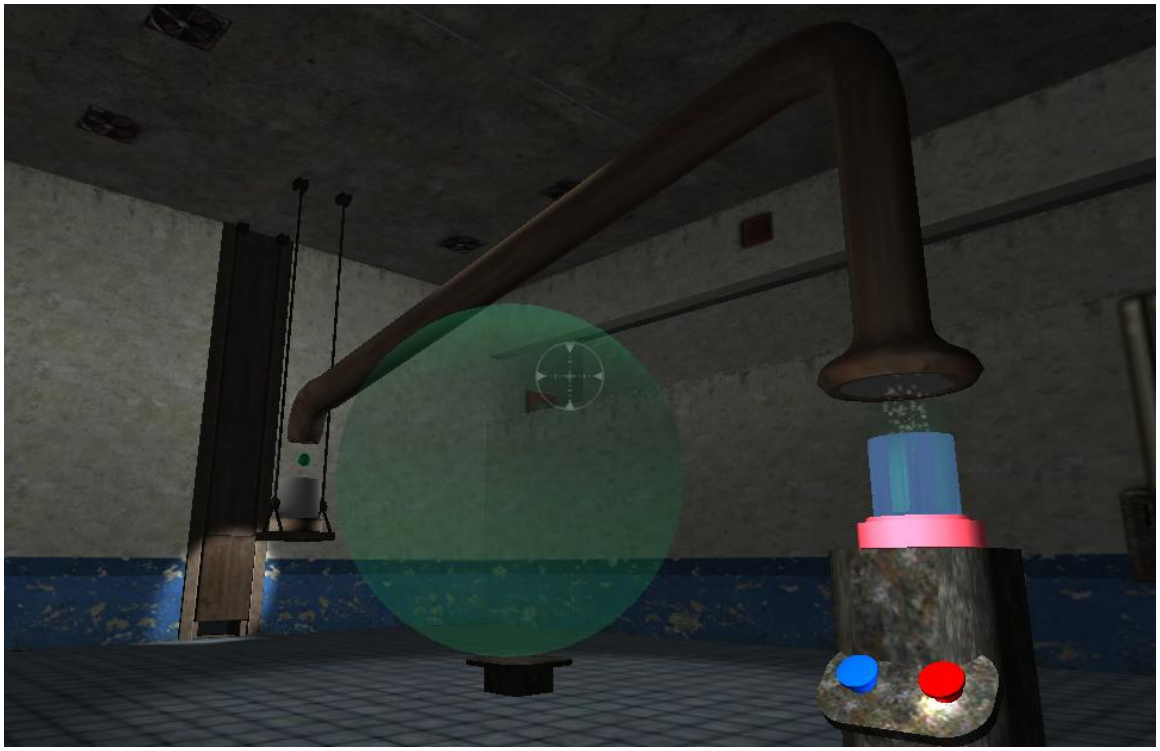


Figure 3. Steam collection

To help students in understanding what is occurring at a molecular level, students can click on the hood, or on the water sink, and the molecular view appears in the large central orb, as shown in Figure 4:

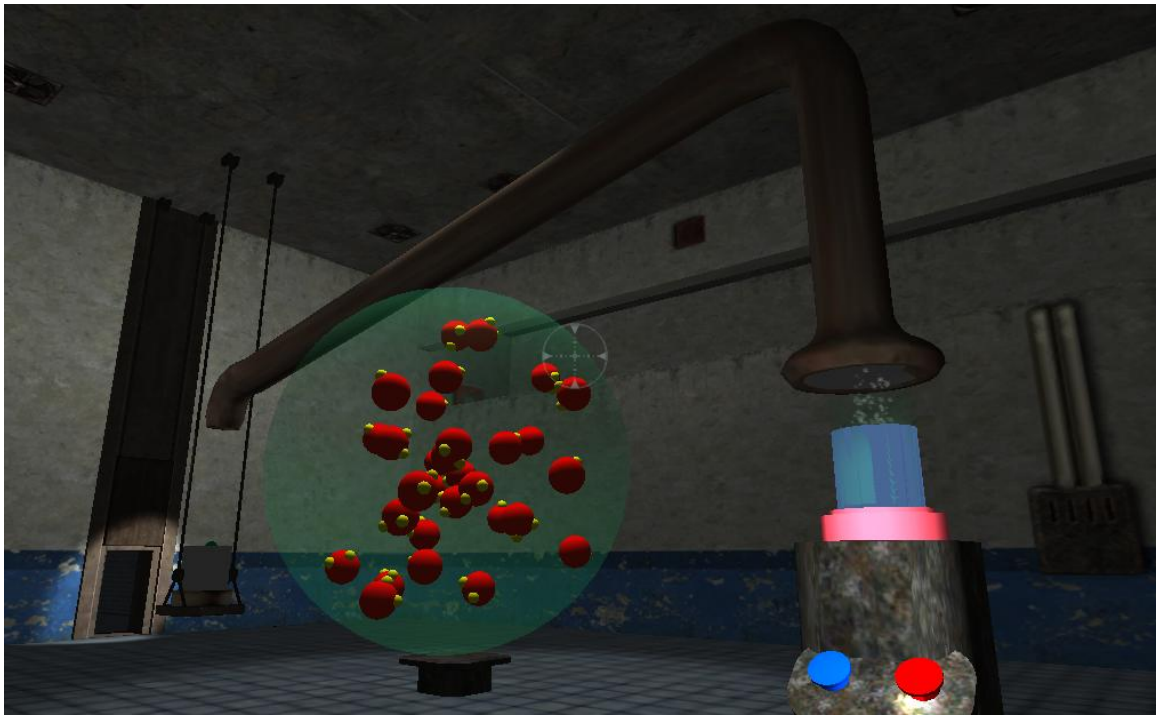


Figure 4. Molecular view of vapors

When students click on the green button, the steam will stop, the bucket will stop filling and the water in the sink will convert to ice as shown in Figure 5:

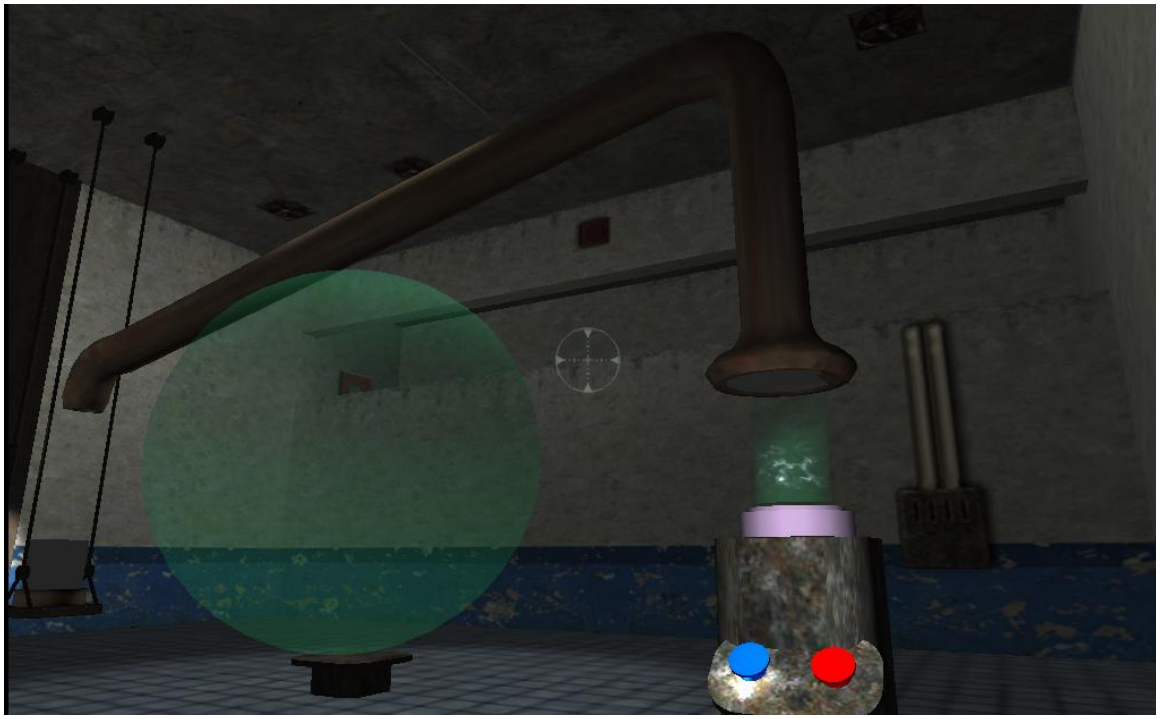


Figure 5. Ice formation

When students click on the bucket, they again activate the molecular view in the orb. This time the molecular view of ice is displayed because water in the sink is in ice form as shown in Figure 6:



Figure 6. Molecular view of ice

Note that the alignment of the molecules mimics the nature of ice. Students need to understand and view these molecular alignments in order to apply this information in later assessments. When students travel through the door they encounter a portal as shown in Figure 7:

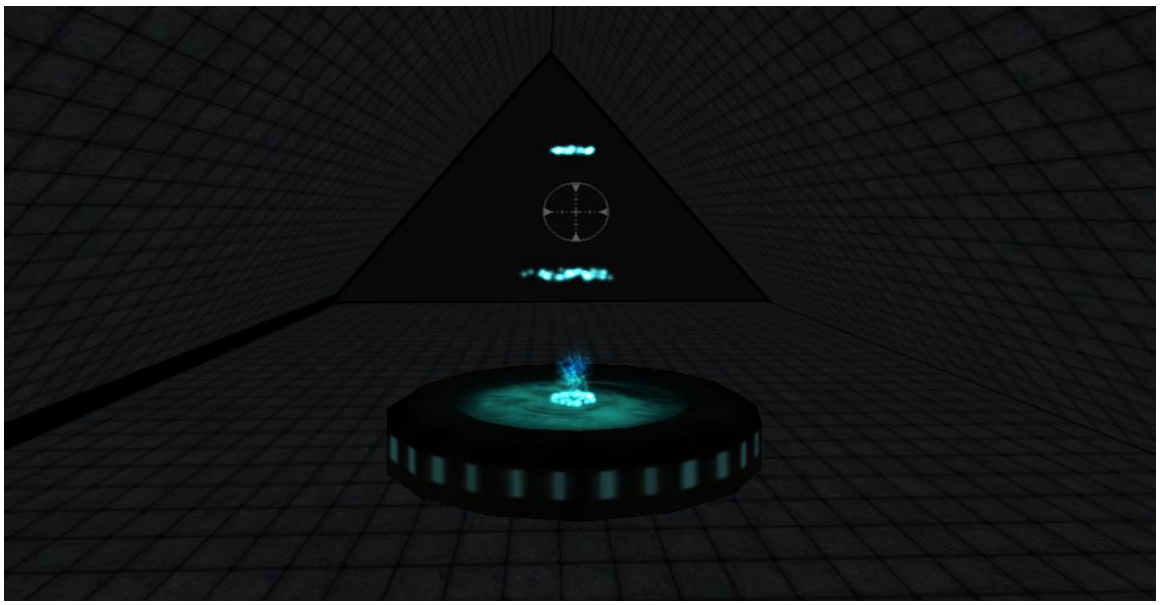


Figure 7. Portal to activate assessment

Once the player jumps on this portal, it activates the assessment as shown in Figure 8:



Figure 8. Assessment Window

Once in this assessment, students are required to answer a series of questions related to the molecular nature of the water to demonstrate their comprehension of the concepts. They may continue to explore and work on this level as long as it takes for them to understand the concepts and develop what they need.

Student performance data is collected from the simulation environment through an automated program built into the simulation itself. The data is posted to a RESTful web-application running in the Heroku's Cloud. In order to be able to associate data with individual learners, they are required to login with a username before beginning. The assessment data is populated in real-time into a database and can be viewed as soon as the player finishes the assessment. Figure 9 shows the real time data capture.

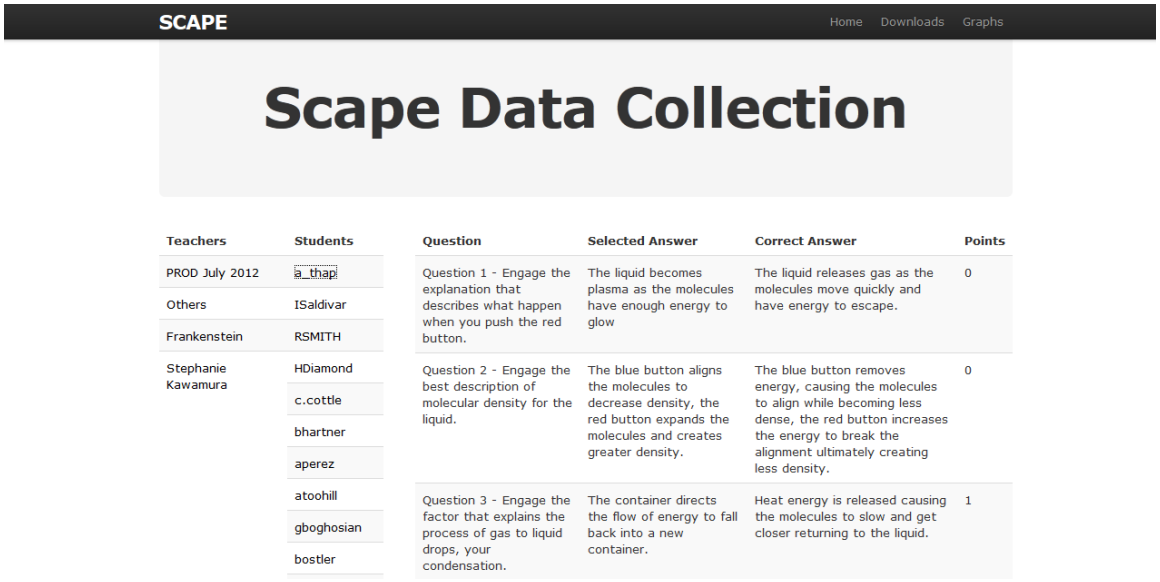


Figure 9. S'cape data collection website

The S'cape data collection application provides a way to download the data. Downloaded data is in excel format which is supported by all major data analysis tools. Figure 10 shows the data download page.

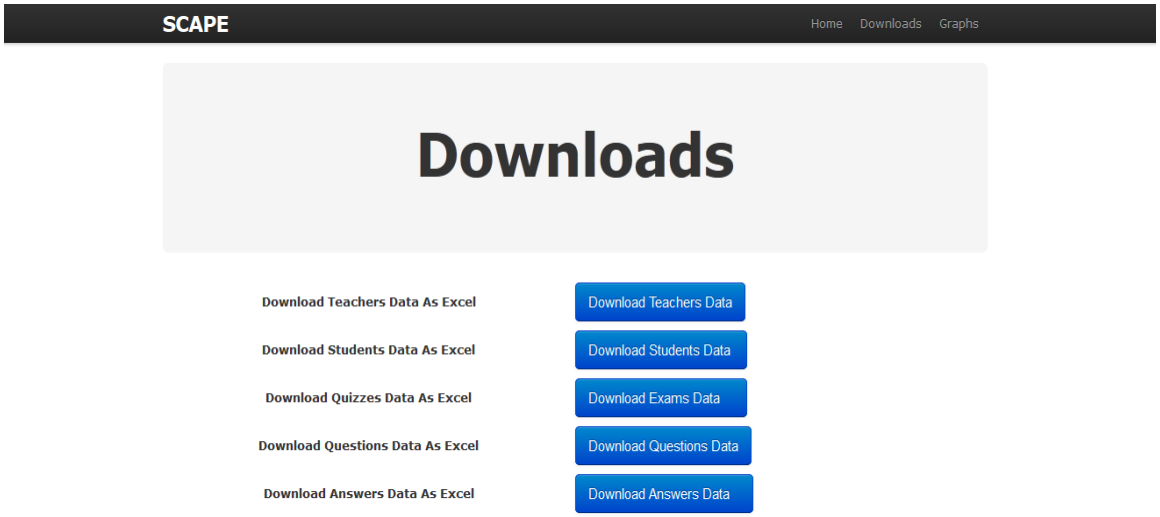


Figure 10. S'cape data download page

Curriculum Standard links level one:

These activities connect to

- objective one,
  - sub-goal A (differentiating differences in physical properties),
  - sub-goal B (classifying substances based on physical properties), and
  - sub-goal C (Investigate and report on physical properties of a particular substance);
- objective two,
  - sub-goal A (identifying observable evidence of physical change;
- objective three,
  - sub-goal A (Identify kinds of energy as substance undergoes physical change),
  - sub-goal B (Relate amount of energy in the motion of molecules in substance),
- objective 4,
  - sub-goal A (Identify reactants and products in a chemical change and describe the presence of atoms in both reactants and products)

CHAPTER 3 SOLUTION DESIGN

3.1 Overview

The architecture of S'cape can be divided into three components:

- Unity3D game objects,
- Assessment system, and
- Data collection web application;

Figure 11 shows S'cape architecture in terms of its component.

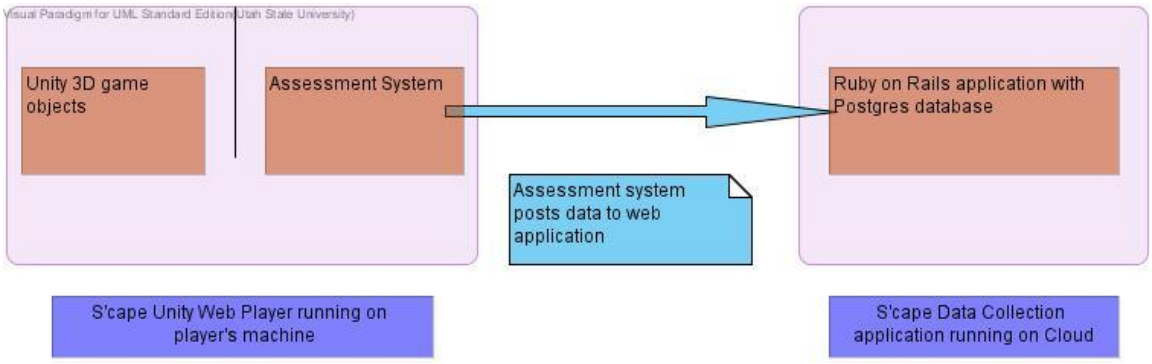


Figure 11 Overall architecture

3.2 Unity 3D game objects design

Unity 3D supports writing scripts in C#, JavaScript and Boo. A single project can use any combination of the languages. Scripting inside Unity consists of attaching custom script objects to game objects. These custom objects are called behaviors in Unity. Different methods inside the script object are called on certain events. Figure 12 shows main

classes and packages for the S'cape game. The package Replay Regen contains classes and methods for replaying player's actions at the time of assessment.

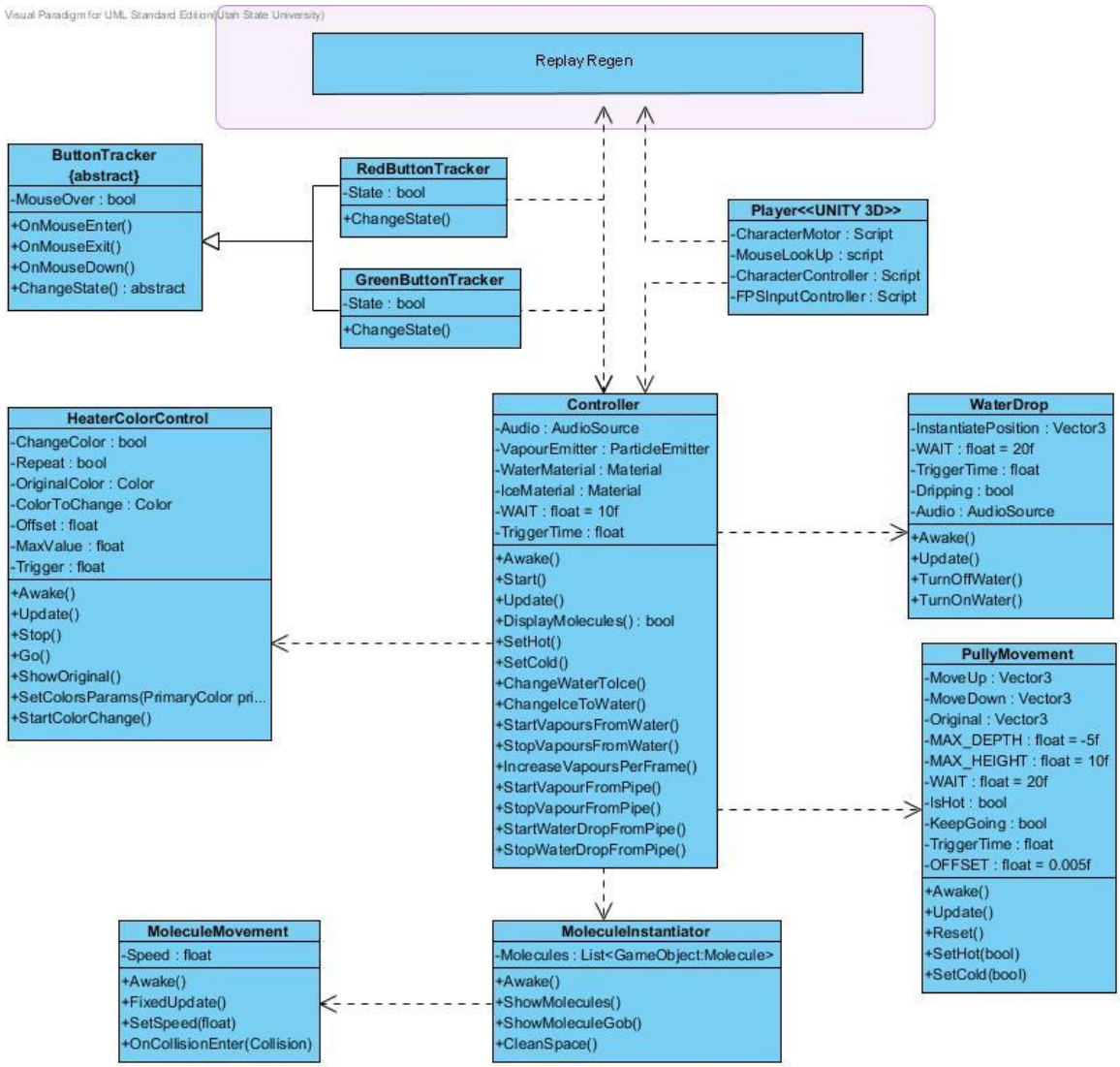


Figure 12. Game object class diagram

Game objects interact with each other depending on the player actions. In S'cape, hot spots (water sink and pipe hood) are responsible for rendering the molecular view of water in the central orb (spherical transparent game object).

3.3 Assessment system design

Assessment in S'cape follows a quiz like pattern. While taking the assessment, players virtually discuss the science that helped in their escape. The questions are designed with a scale for more expert like understandings to novice like understandings. An accurate response is worth two points. An answer this is semi-correct and demonstrates a level of understanding is worth one point. Each answer also has an associated feedback that is given to the player. Figure 13 shows various classes involved in the assessment system.

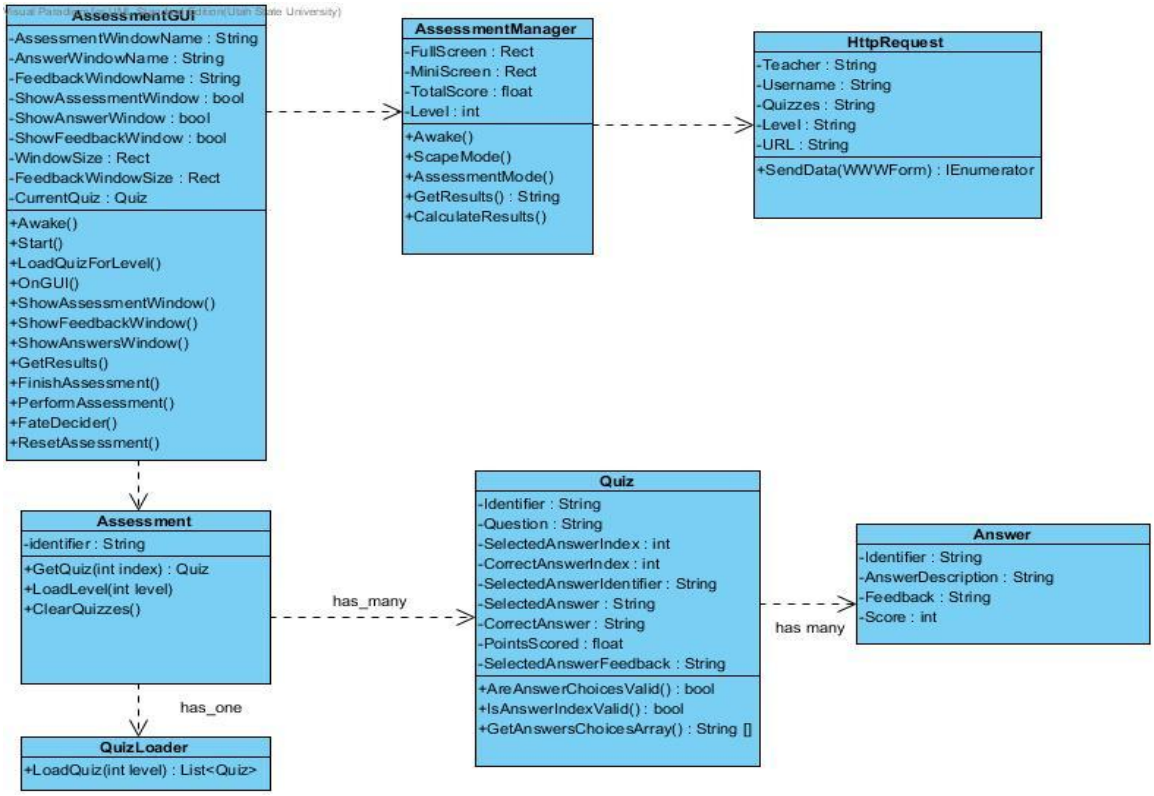


Figure 13. Assessment system class diagram

If players cannot reach a certain threshold of points based on their selected answers, they are sent back into the room to re-investigate what they may have missed in the first attempt.

3.4 S'cape data collection design

Player assessment results are collected from the simulation environment by posting the data to a web application (http://scape.herokuapp.com/). It is a Ruby on Rails application with Postgres 8.4 as database (currently Heroku only supports Postgres). Figure 14 shows the interaction between S'cape web player and data collection app.

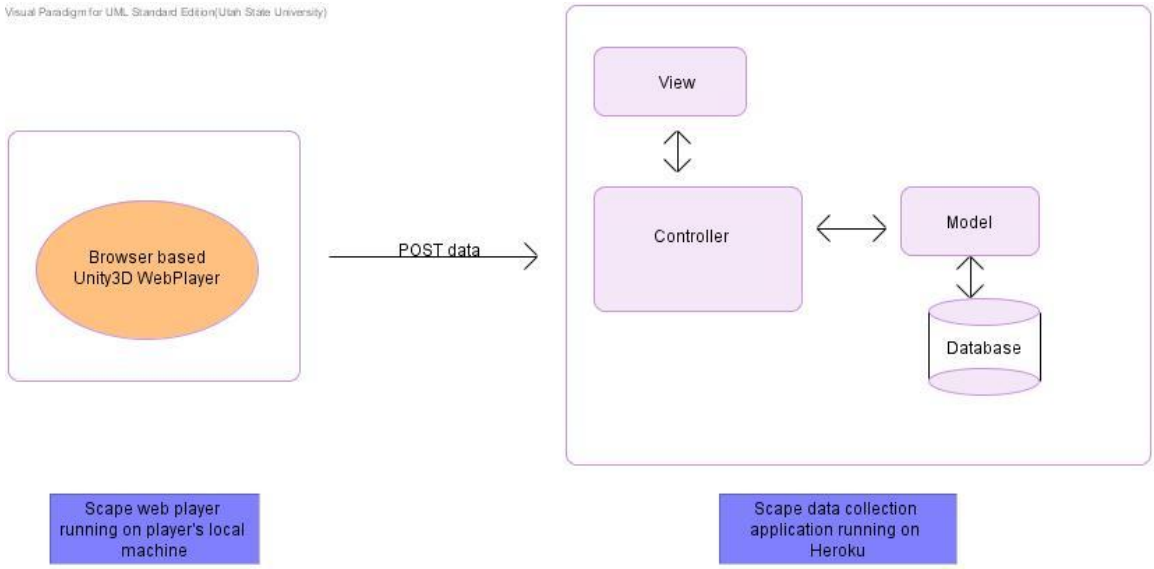


Figure 14. Data collection architecture

The crux of the data collection application lies in the data model which describes how data is being saved in the database. An Entity-Relationship model (ER model), which describes a database in an abstract way, is shown in Figure 15:

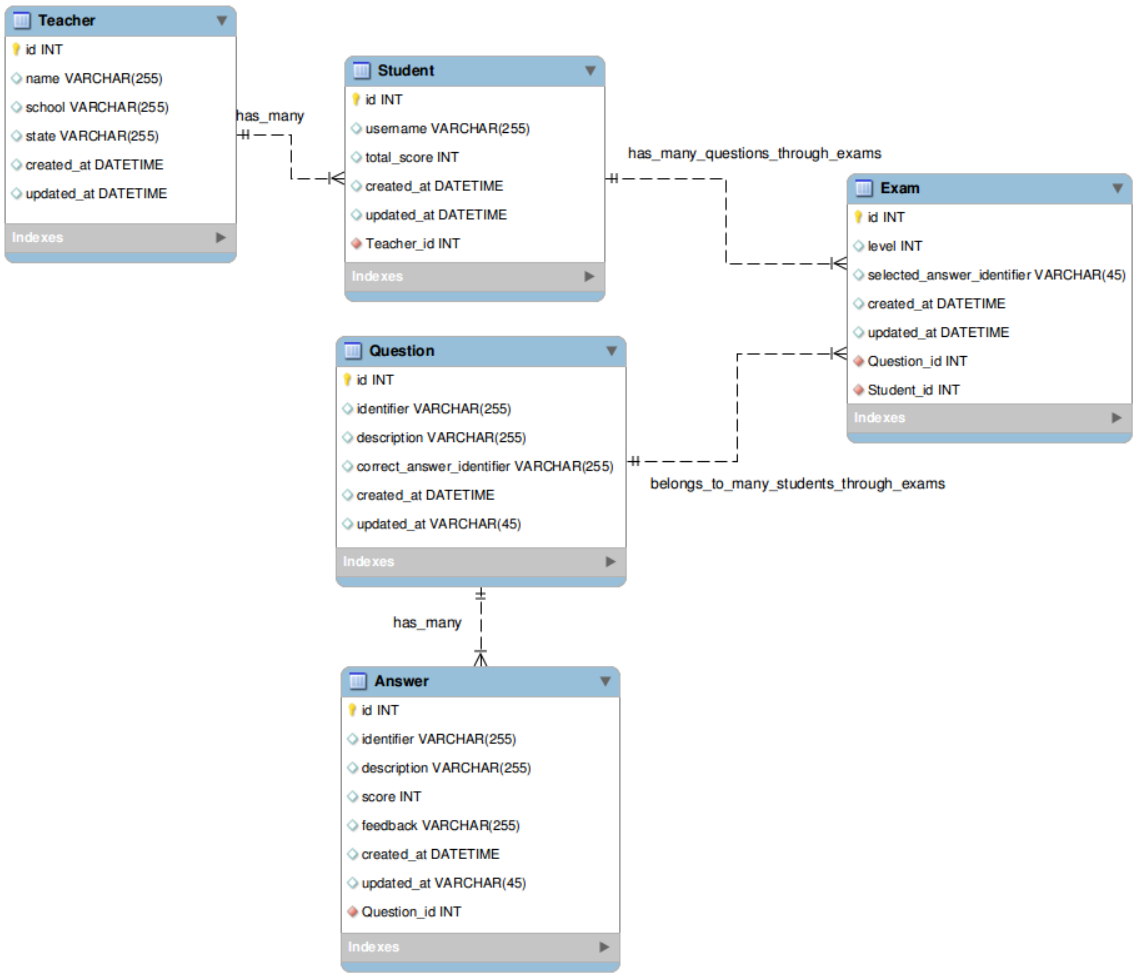


Figure 15. Data collection ER model

The above diagram shows the various tables and the relationships between them.

CHAPTER 4 RESULTS

S'cape was piloted with sixty ninth grade students in a rural charter high school. Students were divided into two groups of thirty each. Four of the students never met the threshold of 8 out of 10 possible points. While a lack of companion instructions likely affected their attempts, as this simulation will be implemented within a structured curriculum, it is difficult to correlate this lack of instructions to the results here. Those students who completed the assessment on their fourth or later attempts, exhibited sign of exhaustion with the system. Students who completed the assessment in three or less attempts clearly showed improved scores on each attempt. Figure 16 shows the overall analysis of the collected data.

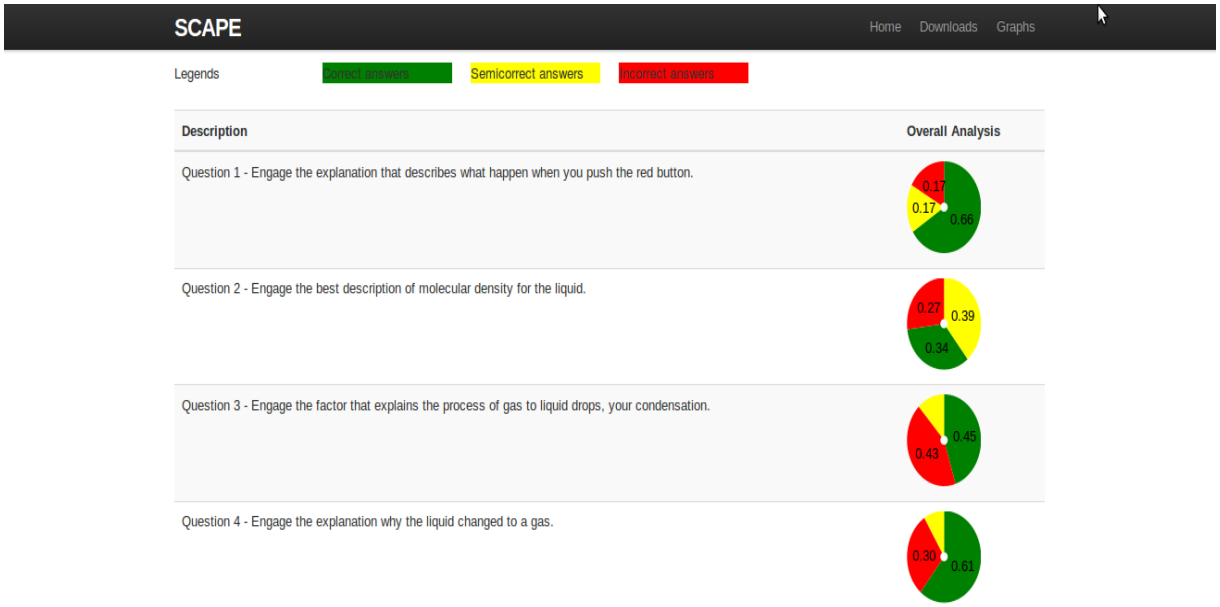


Figure 16. Analysis of assessment

Note that semi-correct answers corresponds to those answers which are close to correct answer and carry one point. From Figure 16 it is clear that the first question was answered correctly by most of the students. Question one asks, “Engage the explanation that describes what happens when you push the red button.” Possible responses include:

- the liquid becomes a solid because the molecules are moving more slowly,
- the liquid releases gas as the molecules move quickly and have energy to escape,
- the liquid becomes plasma as the molecules have enough energy to glow,
- the liquid remains unchanged as a liquid;

Depending on the selected answer, corresponding feedback include:

- Not quite--observe the globe more closely (worth 1 point),
- Observant Human! Consider cooking with grease or water with the loss that boiling brings with it (worth 2Points),
- Looking closely, is there any observable light emission? (no points),
- Not an observant human;

Collected data also shows that thirty-seven students passes the assessment in the first attempt. Maximum number of attempts made to pass the assessment being equal to eight. The average of the number of attempts was calculated to be 1.9 times. Figure 17 represents the line graph of number of attempts for each user in sorted order.

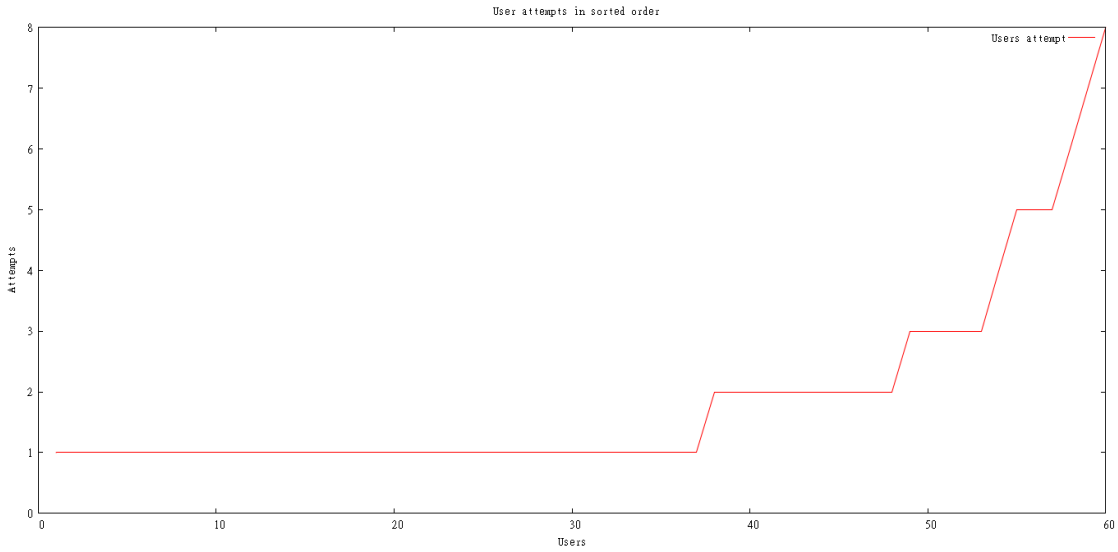


Figure 17. Number of attempts made in sorted order

Figure 18 represents the distribution of number of attempts.

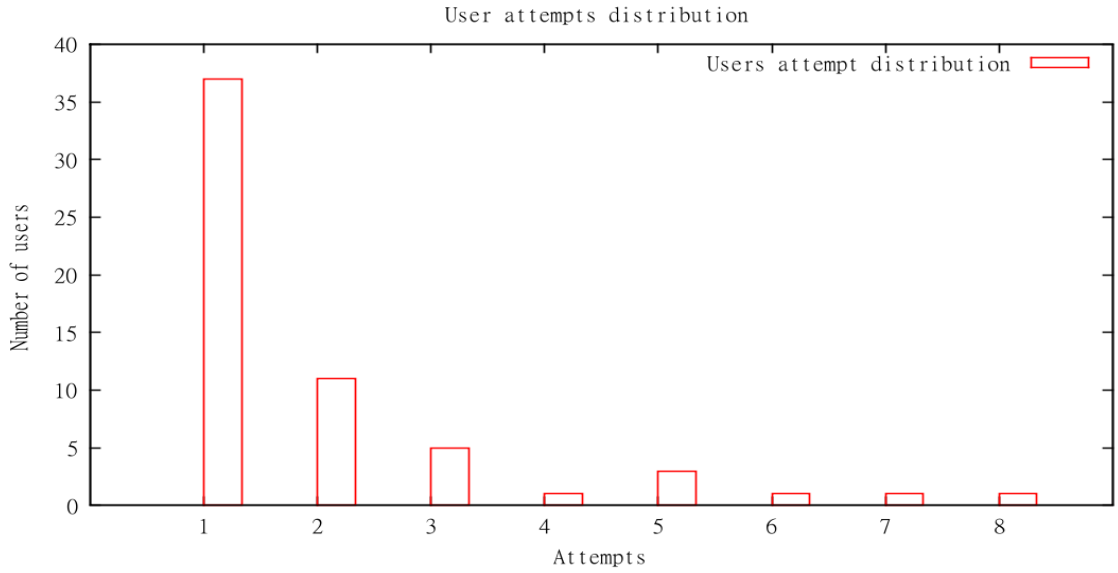


Figure 18. Distribution of number of attempts

CHAPTER 5 CONCLUSION

It is significant to note that 23 of the 60 students did not pass the assessment the first time and were returned to the simulation before attempting again. Even though 37 passed on the first attempt through the level, the average number of attempts was 1.9 times. Based on these results it appears that the level of difficulty was appropriate for the grade level although challenging for most students. Teachers reaction to the project was very good and they liked the idea of displaying molecules in the central orb. On a side note, S'cape also participated in the STEM video game challenge 2012.

Automated assessment feature holds great advantage over the paper based assessments in terms of time and availability of results. Teachers don't have to check the results manually and then guide students as per the score achieved because this is all done automatically.

Being web-browser based not only lends S'cape to accessibility in remote communities, but also provides a simple means for practical updating and sustainability. No other hardware or software is needed except a browser plug-in. In addition, being browser-based makes it possible to be used in schools without requiring additional software to be installed.

REFERENCES

[1] Jeffery A. Olsen, Brett Shelton, 2012. S'cape from formality : Embedded and Automatic Assessment within Simulation Games

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[9] D3.js - Data Driven Documents

[10] Unify Community Wiki - Place to find and share Unity knowledge

APPENDICES

Appendix A: Content of the file Quizzes.xml

```
<?xml version="1.0" encoding="utf-8" ?>
<questions>
  <question text="Question 1 - Engage the explanation that describes what happen
when you push \n the red button." answer_index= "1" identifier="L1Q1">
    <answer>
      <identifier>Q1A1</identifier>
      <description>The liquid becomes a solid because the molecules are moving
more slowly</description>
      <score>1</score>
      <feedback>Not quite--observe the globe more closely.</feedback>
    </answer>
    <answer>
      <identifier>Q1A2</identifier>
      <description>The liquid releases gas as the molecules move quickly and have
energy to escape.</description>
      <score>2</score>
      <feedback>Observant human! Consider cooking with grease or water with the
loss that boiling brings with it.</feedback>
    </answer>
    <answer>
      <identifier>Q1A3</identifier>
      <description>The liquid becomes plasma as the molecules have enough energy
to glow</description>
      <score>0</score>
      <feedback>Looking closely, is there any observable light
emission?</feedback>
    </answer>
    <answer>
      <identifier>Q1A4</identifier>
      <description>The liquid remains unchanged as a liquid.</description>
      <score>0</score>
      <feedback>Not an observant human. Observe the contents of the globe more
closely.</feedback>
    </answer>
  </question>
  <question text="Question 2 - Engage the best description of molecular density
for the liquid." answer_index= "3" identifier="L1Q2">
    <answer>
      <identifier>Q2A1</identifier>
      <description>The blue button aligns the molecules to become more dense, the
red button spreads \n the molecules to less density.</description>
      <score>1</score>
      <feedback>The reason for the density changes remains ambiguous. What do the
buttons do to create those changes?</feedback>
    </answer>
    <answer>
      <identifier>Q2A2</identifier>
      <description>The blue button aligns the molecules to decrease density, the
red button \n expands the  molecules and creates greater density.</description>
```

```
      <score>0</score>
      <feedback>No, access the definition of density and observe the globe
again.</feedback>
    </answer>
    <answer>
      <identifier>Q2A3</identifier>
      <description>The density of the materials remains the same from red to blue
button.</description>
      <score>0</score>
      <feedback>That doesn't seem correct. More observation is needed of the
molecules.</feedback>
    </answer>
    <answer>
      <identifier>Q2A4</identifier>
      <description>The blue button removes energy, causing the molecules to align
while becoming \n less dense, the red button increases the energy to break the \n
alignment ultimately creating less density.</description>
      <score>2</score>
      <feedback>Observant human. Application of heat energy dramatically changes
how dense the molecules are.</feedback>
    </answer>
  </question>
  <question text="Question 3 - Engage the factor that explains the process of gas
to liquid drops, your condensation." answer_index= "2" identifier="L1Q3">
    <answer>
      <identifier>Q3A1</identifier>
      <description>The less dense gas molecules escape causing the dense liquid to
fall.</description>
      <score>0</score>
      <feedback>No, this does not relate directly to factors of
density.</feedback>
    </answer>
    <answer>
      <identifier>Q3A2</identifier>
      <description>The molecules change to a different chemical in the air and
falls back to the water.</description>
      <score>0</score>
      <feedback>Not an oberservant human. We observe no chemical change in
globe.</feedback>
    </answer>
    <answer>
      <identifier>Q3A3</identifier>
      <description>Heat energy is released causing the molecules to slow and get
closer returning \n to the liquid.</description>
      <score>2</score>
      <feedback>Observant human. Similar to your ice water glass on a hot day
leaving a water ring on a table.</feedback>
    </answer>
    <answer>
      <identifier>Q3A4</identifier>
      <description>The container directs the flow of energy to fall back into a
new container.</description>
      <score>1</score>
      <feedback>Not quite, as the container bears little effect.</feedback>
```

```
    </answer>
  </question>
  <question text="Question 4 - Engage the explanation why the liquid changed to a
gas." answer_index= "0" identifier="L1Q4">
    <answer>
      <identifier>Q4A1</identifier>
      <description>Heat energy caused the molecules to move faster and farther
apart until some \n molecules have enough energy to escape as a gas.</description>
      <score>2</score>
      <feedback>Observant human. Ponder why a fog appears on a pond some
mornings.</feedback>
    </answer>
    <answer>
      <identifier>Q4A2</identifier>
      <description>The liquid changed into a gas when heated because it expands
and the container \n can no longer hold it.</description>
      <score>1</score>
      <feedback>Not quite, as the container bears little effect.</feedback>
    </answer>
    <answer>
      <identifier>Q4A3</identifier>
      <description>The molecules change to a different chemical that is a gas and
\n escapes from the water.</description>
      <score>0</score>
      <feedback>We observe no molecular change in globe.</feedback>
    </answer>
    <answer>
      <identifier>Q4A4</identifier>
      <description>when the liquid was heated, molecules of gas are dissolved and
rise and escape \n because they are less dense.</description>
      <score>0</score>
      <feedback>Please dismiss factors of density.</feedback>
    </answer>
  </question>
  <question text="Question 5 - Engage the explanation of what changes for a
chemical or physical change to occur." answer_index= "2" identifier="L1Q5">
    <answer>
      <identifier>Q5A1</identifier>
      <description>Change in mass.</description>
      <score>1</score>
      <feedback>No, as mass requires additional stimuli.</feedback>
    </answer>
    <answer>
      <identifier>Q5A2</identifier>
      <description>Change in size.</description>
      <score>0</score>
      <feedback>No, since there are other factors that would affect
size.</feedback>
    </answer>
    <answer>
      <identifier>Q5A3</identifier>
      <description>Change in energy.</description>
      <score>2</score>
```

```
      <feedback>Observant Human. Without an energy input what would happen to the
state of the liquid?</feedback>
    </answer>
    <answer>
      <identifier>Q5A4</identifier>
      <description>Change in color.</description>
      <score>0</score>
      <feedback>No, color change results from other stimuli.</feedback>
    </answer>
  </question>
</questions>
```

Appendix B: Content of the file user_attempts_gnu.txt (used in gnu plot)

```
set title "User attempts in sorted order"
set xlabel "Users"
set ylabel "Attempts"
set yrange [0:8]
plot 'path/To/Datafile.dat'  with lines title 'Users attempt in sorted order'
```

Appendix C: Content of the file user_attempts_distribution_gnu.txt (used in gnu plot)

```
set title "Users attempt distribution"
set xlabel "Attempts"
set ylabel "Number of users"
plot 'path/To/Datafile.dat'  using 2: xtic(1) with histogram title 'Users attempt distribution'
```