How effective is the computer game model for teaching chemistry?

Phase II

Kermin Joel Martinez-Hernández
Gabriela C. Weaver
Department of Chemistry
Chemical Education Division
Purdue University

Phase I: Summary

Games Evaluated

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Action/FPS</th>
<th>Adventure/Role Playing Game (RPG)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Phase I: Summary

Purpose:
Investigation of the elements of game design that lead to motivation for continued play

Major Findings:
- Students appear to favor the game genres:
  - Strategy: Female
  - Action/1st Person Shooter: Males
  - Role Playing Games (RPG): Both
- Games that are engaging should incorporate elements of these three genres.

Chemicus

- Adventure game similar to a popular game (Myst™)
- Includes exploration and unlocking secrets using chemistry knowledge
- Only educational chemistry game available commercially
- Received lowest ratings overall from students

Student Assertions from Chemicus

**Dislike - the game is hard or difficult**

"...And I dislike that sometimes it’s very confusing, like if I didn’t have the manual I couldn’t find some things, some things are very hard to find in the room or hard to figure out... so I wish there would be more hints in the game itself to help you figure out which elements go together as opposed to just...walking around for a while, there are some things I couldn’t get even with the manual. I still didn’t get some things. This is what I didn’t like."

- 42% of students had similar comments
Evaluation of Chemicus in Phase II

- Students did not like or enjoy playing with Chemicus™.
- However, we are still interested to know if they learn chemistry from it.
- Also, further investigation of students’ reasons for disliking.

Phase II Research Questions

- Is there a difference in the level of conceptual understanding between students who played Chemicus™ and those who carried out the same activities in a hands-on format?
- Conceptual Understanding - "ability to recognize underlying concepts in a variety of different representations and applications"


Research Design

- Students played Chemicus in addition to attending their general chemistry class where the same concepts are taught.
- Game players were compared to another group who carried out chemistry hands-on activities, but did not play the game. Attended the same chemistry class.
- Pre and post content tests were used to assess changes in student understanding using chemistry-related games.
- Think-aloud methods were used to monitor student activities during game play.

Description of the Sample

- Voluntary sample of college students
  - N = 11, 4 females and 7 males
- Volunteers recruited by announcements in a general chemistry course
- Randomly divided into two groups:
  - Video game (3 males and 2 females)
  - Hands-on (4 males and 2 females)

Description of the Sessions

- Hands-On Sessions (H.O.)
  - ten sessions of one hour each in which similar topics that are presented as in the game
  - recitation-style supplementary instruction
  - students completed discovery type experiments without detailed instructions
- Video Game Sessions (V.G.)
  - Students played Chemicus™ for a maximum of ten hours over several weeks
- Presence of Researcher
  - H.O. → students work on their own and then a wrap-up discussion sections was conducted with researcher
  - V.G. → students played with the game on their own and asked questions to the researcher if needed
Description of Assessment Instruments

- Pre and post content tests were developed to **assess content knowledge** before and after the game or hands-on session intervention.
- Interviews were conducted **after each hour** of game play or hands-on session.
- Interview questions were designed to get evidence of deeper possible conceptual understanding.

Pre & Post Content Data Analysis

**Average Change in % of Correct Answers**

<table>
<thead>
<tr>
<th>Gender</th>
<th>Treatment</th>
<th>Hands-On</th>
<th>Video Game</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>7.8%</td>
<td>13.0%</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>2.6%</td>
<td>0.0%</td>
<td></td>
</tr>
</tbody>
</table>

- Small Sample Size → N = 11
  - H.O. → n = 6 (4 males and 2 females)
  - V.G. → n = 5 (3 males and 2 females)

**Concept Recognition**

- Student **mentions a concept** but no further explanation is provided (i.e. pH levels, symbols, power, acid, base, fuel cell, distillation, rust, etc.).

"Uhm... we had prior knowledge beforehand. For instance, lemon juice we knew that it’s very acidic or close to being very acidic. So, I remembered that pink was acidic so I put it in that side and milk was neutral we put it in the center" (Student No. 328, H.O.).

"some acids and bases... pH changes become more acidic if it’s lower and if the solution gets basic, the pH gets higher... also changes in color, the more acidic turn red and the more basic turn blue..." (Student No. 345, V.G.).

Interview Data Analysis

- Transcribed and coded to look for:
  - Concept recognition
  - Concept development
  - Concept application
  - Use of previous knowledge
### Concept Development

- Student indicates their understanding of a concept **has been helped** by the video game or by the hands-on session.

> “I think that I learned how... different like... different atoms are based in organic compounds and how to predict what atoms are in an organic compounds. And also how to draw organic compounds and how to predict the structure of organic compounds...”
> (Student No. 414, H.O.).

> “I learned the atomic structure of C₁₀H₂₀O and how the different atoms are formed together in a molecule...” (Student No. 350, V.G.).

### Concept Application

- Student knowingly **relates a concept** to meet a challenge in the video game or the hands-on session and/or when she/he references a real-life application of a concept.

> “I like being able to test with household objects... I enjoyed the experiment specifically with household cleaner or vinegar or some. All these things you don’t use in lab, but anyway something else, orange juice or something because I drink orange juice. I like thinking, oh wow, I knew it was acidic, this is how acidic, or this much acidic.”
> (Student No. 719, H.O.)

> “The game helped me to relate some chemistry concepts to real life situations or real life objects... but it didn't really help me too much with chemistry 116 concepts.”
> (Student No. 345, V.G.)

### Use of Previous Knowledge

- Student **mentions or gives evidence of prior knowledge** of the chemistry or some other aspect of the situation encountered.

> “For learning of periodic table. A lot of CHM 116 concepts are just basic overview of the elements in the periodic table... and the... uhm... which one is a metal and stuff like that”
> (Student No. 313, H.O.).

> “I have seen this in a chemistry class... I remember doing the puzzle. I didn’t need to look at the pamphlet that tin was Sn, I just knew that for instance beforehand. And tin is close to gold”
> (Student No. 028, V.G.).

### Conclusions

- Students in both treatments were able to:
  - recognized chemistry concepts
  - further developed chemistry concepts & believe that they learned chemistry
  - used real-life applications to apply in their concept development
  - used their previous knowledge to identify chemistry concepts

- We do not see statistically significant differences in the effects of the treatments, possibly due to low sample size.

- VG holds promise as an educational tool.

### Educational Implications

- Video Games may be a possible **learning setting** for students to learn chemistry concepts.

- This study suggested that games should provide enough hints, further explanation, and an easy navigation structure to get the concepts across.
  - Lack of these leads to excessive **frustration** for the students and a sense of “not liking” the game.

### Educational Implications, cont.

- If educational material fails to wrap-up and make conclusions from the concepts, student may be interacting with the material but they may not be learning from it.

- Manipulation of 3D or virtual 3D representations of a chemistry phenomenon seems to help for developing better conceptual understanding (i.e. 3D adrenaline molecule in VG vs. 2D in HO).
Acknowledgements

- Weaver Group
  - Douglas D. Danforth
- Nahyr D. Rovira-Figueroa
# DUE-0443045