How effective is the computer game model for teaching chemistry? Phase II

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

Phase I: Summary

Games Evaluated

Strategy

Action/FPS

Adventure/Role Playing Game (RPG)

Adventure (Educational)

Simulation (Flight/Strategy)

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

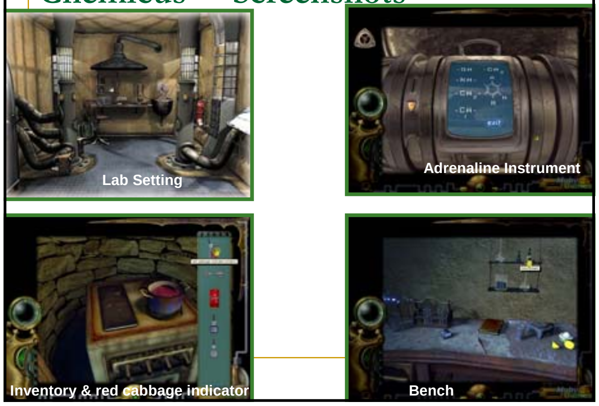
- Adventure game similar to a popular game (Myst^{TM})
- Includes exploration and unlocking secrets using chemistry knowledge
- Only educational chemistry game available commercially
- Received lowest ratings overall from students

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

Chemicus™ Screenshots



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.

8

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"

Reference: Richardson, R. R., & McCallum, W. G. (2003). The third R in literacy. In Madison, B. L., & Steen, L. A. (Eds.) *Quantitative literacy: Why numeracy matters for schools and colleges*, (pp. 99-106). National Council on Education and the Disciplines, Princeton: New Jersey.

9

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 asses changes in student understanding using chemistry-related games.
- **Think-aloud** methods were used to monitor student activities during game play.

10

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)

11

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

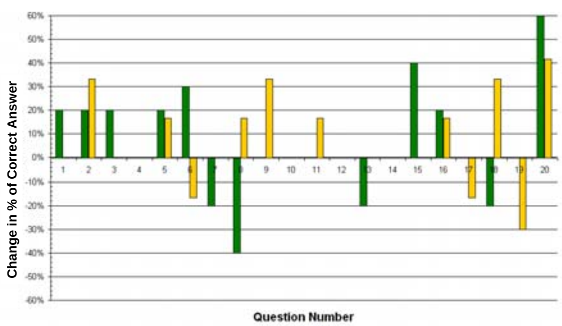
12

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

Change in % of Correct Answer b/w Pre & Post Content Test Surveys



t-test, p = 0.61

V.G. 6.8% vs. H.O. 7.6% of Average Change in % of Correct Answers

Average Change in % of Correct Answers

Gender	Treatment	
	Hands-On	Video Game
Male	7.8 %	13.0%
Female	2.6 %	0.0%
	p = 0.92	p = 0.07

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

Interview Data Analysis

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

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. 028, 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.).

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 $C_{10}H_{20}O$** 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
- NSF # DUE-0443045