Learning and teaching through games 2nd June 2015

Games in chemistry: two recent examples of a card-card and a boardgame for use as educational resources

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OVERVIEW

Context: games in chemistry

Design & development (academic-led / student-led)

Stages of this talk:

- 1. "Green Chemistry" board-game outline
- 2. "Laboratory Manager": card-game outline
- **3.** More games-in-science project ideas
- 4. Conclusions



Games in chemistry

Not as common as in some other subject areas

- High "input" requirements
- Traditional focus: lectures, labs, workshop tutorials
- New approaches gaining traction (PBL, flipped-learning)
- Recognised need to attract students to "difficult" subject (RSC Outreach, flash-bang demonstrations)

Advantages of using game resources?

- Something different and engaging
- Session experience: learning without fear of mistakes
- Small groups of students directly interact: peer learning; cohort cohesion

Game design & development: those involved

Green Chemistry (Board-game)

Academic-led design/development HEA funding Development: Dan Rawlins (3 week summer employment)



Laboratory Manager (Card-game)

Student-led design/development

Kevan Garvey (main design, 2014) building on initial ideas of Nicola Humphreys & Liam Smith (both 2013): u/g final-year projects.

Roberta Fabricio Loose (2014-15): work experience. Refinements & extension of the design.

1. Green Chemistry: board-game

AIM: Introduce the "12 principles of green chemistry"

Target: undergraduate chemistry/chemical science students

- Free-of-charge
- 3-6 players 🎇
- 🕗 60 minutes
- Decision-based game (low luck element)¹
- Winner is s/he with most money at the end of the game

¹ **Coffey, M. (2014)** Green Chemistry: classroom implementation of an educational board-game illustrating environmental sustainability in chemical manufacturing in *Handbook of Research on Pedagogical Innovations* for Sustainable Development (pp. 453-473). Eds: K.D.Thomas & H. E. Muga. IGI Global.

The twelve principles of green chemistry

Anastas, P. and Warner, J. (1998) Green Chemistry Theory and Practice. OUP, London.

- ^{1.} Prevention of waste is better than treatment
- ^{2.} Maximise atom economy during synthesis
- ^{3.} Use and generation of low toxicity substances where feasible
- 4. Use safer solvents and auxiliary substances
- 5. Design substances with specifically targeted toxicity
- 6. Design processes that are energy efficient
- 7. Use renewable or sustainable feedstock
- 8. Reduce synthetic steps, minimise derivatisation
- 9. Use selective catalysts, improving on stoichiometry
- 10. Design degradable products
- ^{11.} Adopt real-time in-process monitoring for optimisation
- ^{12.} Incorporate scope for reducing hazards and accidents.

The Game: outline of play (1)

Player manages a chemical manufacturing site.

Over 6-7 rounds:

- invest in manufacturing technologies (processes).
- Buy raw materials as process feedstock.
- Buy required energy.
- Recoup money as sold products.

Each production cycle generates waste, ("bulk" or "special"). Pay for disposal on an escalating scale.

Players can invest in "on-site" waste treatment, and "onsite" energy generation.

Each technology (process) can be upgraded to its Green Chemistry alternative.

Game end, player with most money (not assets) wins.





The Game: outline of play (2)

Process has STD and ADV (Green Chemistry) versions

ADV has fewer feedstock needs and generates less waste (and/or less energy)

Text card outlines process; footnote indicates which of 12 principles illustrated by the example



STD 4 Polystyrene

- 'Foamlike' properties incorporated using CFC's and HCFC's as blowing agents.
- CFC's cause global warming and ozone depletion
- CFC's and HCFC's also flammable

ADV 4 Polystyrene

- Process now uses CO₂ as blowing agent.
- CO₂ is safer as non-flammable
- CO₂ not ozone depleting and has lesser global warming potential 1, 3, 4, 12

The Game: outline of play (3)

Two formats of game: Basic and Advanced

Advanced game includes:

- Energy use limits(reflecting emission trading scheme)
- Option to increase production (and waste) rate
- Players can trade waste or energy use capacity: more interactive game



Lessons from "Green Chemistry"

<u>Up-sides</u>

Where presented ^{2, 3, 4} found favourable interest especially in European countries (Germany, Poland, Switzerland, Finland).

Translation into German made at University of Bremen.

- Game resources wanted by HE chemists (and students)
- Playing with others was enjoyable (social)
- The Green Chemistry game was largely enjoyed as an activity

<u>Down-sides</u>

Components take time to print/assemble. Probably hurdle to adoption.

Game has steep learning curve and is fairly lengthy (how-to-play videos; basic & advance versions available).

Educational value of game enhanced through ancillary activity.







² ViCE 2011 (University of York, UK)

³ Eurovariety 2013 (University of Limerick, RoI)

⁴ Chemistry Education Research: ESD 2014 (Bremen University, Germany)

2. Laboratory Manager Card-game

AIM: task-based introduction to instrumental chemical analysis

Target: transition secondary – tertiary education students

- - Free-of-charge 2-4 players
- 30 minutes (4 hands @ 4-7 min/hand)
- Low complexity (moderate luck factor)
- Winner is s/he with the highest aggregate points values of "correct" cards

Why?

- difficult transition stage for this area of chemistry Ο
- secondary schools/colleges have little instrumentation 0
- mis-match instrumentation theory & practical use 0

The Game: Outline of Play

- 1. All players are presented with the scenario: see example slide
- 2. Players have to assemble hand of cards comprising:
 - . Qualitative or quantitative
 - 2. Analyte Separation
 - ^{3.} Analyte Detection
 - 4. Staff
 - 5. Calibration Certificate
 - 6. Accreditation Certificate
- 3. Play proceeds by turn. Player draws new card from either top of face-up pile or blind from face-down deck, then discards to top of face-up pile.
- Player "Declares" upon completion of hand. Bonus points for Declaring early.
 Solution to scenario is revealed. Player score for each "correct" card collected.
 Running total over 4 or more hands.

3. Laboratory Manager: game design and how-to-play



30 minutes (4 hands @ 4-7 min.)

Set-up for each hand

Randomly choose analytical scenario: all players view. Each player dealt <u>six</u> *Analytical Process* cards.



Hand Scoring

Points scored:

correct analytical separation (3) and detector (3) card held; for quantitative/qualitative card (2) and for staff card (1 or 4). Bonus points for Declaring early.

Play next hand with new scenario until four scenarios are played. Total aggregate points wins the game.

Laboratory Manager : Examples

Scenario (1 of 20)

A major transport haulage firm suspects that one of their drivers may be too dependent on the pain killer *morphine* and that he may be taking it whilst driving: the driver denies this and claims he is fit to drive. Employment terms permit random or selective testing for illegal and legal drug when a driver's ability to carry out their duties is potentially affected.

The company wishes the establish which, if any, drugs are in the driver's system to unequivocally establish whether drug use is a problem. The driver is currently suspended so an accurate blood determination will permit a fair hearing.

Morphine (C₁₇H₁₉NO₃; relative molecular mass 285; boiling point 190°C) Is a naturally occurring *alkaloid* (opiate) organic molecule. It has low volatility and is slightly polar. The detection method is destructive of the sample, creating molecular ions.

Laboratory Manager : Examples

Cards: Analyte Detector (4 of 8)



directly proportional to absorption

(Beer-Lambert Law).

Concentration is directly related to

absorbance.

charge to mass ratio. Relative abundances of each ion are recorded and a spectrum is created.

Educational Focus of Game

To succeed players must:

Choose the appropriate approach (qualitative or quantitative) sample preparative/separation stage and instrumental detection method.

Task focus rather than technical understanding of how the technique works.

Also introduces the concepts of analytical quality control: Discussion opportunity for tutors.



Typical Analylical Chemist Employers:

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Government Agencies; Hospitals; Environment Agencies; Food Industry; Biotechnology; Pharmaceutical; Chemical Engineering

Key Skills:

Theoretical knowledge of analytical technology Communication and presentation Systematic approach to tasks Complex problem solving IT Skills Analytical Skills CALIBRATION

Provides assurances that the analytical instrument delivers accurate results.

Calibration is the process of adjusting the reading of a measurement of an instrument to agree with the value of the applied standard within a specified accuracy.



Accreditation is an important part of the Quality Assurance system of a laboratory

Carried out by UKAS

(UK Accreditation Service)

Measures competences against recognised standards.

Carries out calibration testing and monitoring

Ensures safety and quality

Next stages for "Laboratory Manager" project

- **1.** Refine game scenarios and extend deck.
- 2. Test impact and utility of the game in the classroom
 - 1. Undergraduate student project (2015-16) NOTTINGHAM
 - 2. Play with undergraduate year 1 student focus group
 - 3. Take into sixth-form classroom environment



RSC Outreach Fund Application pending

3. Seek means of offering "physical" version of the game

3. Games-in-science project ideas

Work on science-based game ideas at various stages:

1. Wildlife garden (family/KS2): working proto-type card game

2. Farm manager: pollution prevention game (HE): concept

3. Forensic investigation (HE/transition): concept



Dragonfly



4. Conclusions

- Student-led research project for design "Laboratory Manager". Academic-led design for "Green Chemistry". Both approaches successful.
- Target specific tightly-defined educational purpose.
- Designs available free-of-charge (print-and-play).
- Discipline (staff & students) appreciate game availability.
- Small group informal learning environment activities.

Comments and Questions ?

Thank you for your attention

Proto-type game files freely available: michael.coffey@ntu.ac.uk