Narrative Games in BioAnalytic Forensics

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Abstract: This paper reports on the use of branching path narrative games based on cases written by industry partners and built using Twine in a graduate BioAnalytic Forensics module. The ease of use offered by Twine made it suitable as a tool to quickly introduce industry partners to the concept of interactive narratives which assisted them in framing their case studies. Twine is also an effective tool for introducing these games to students who may be unfamiliar with the genre. Business constraints central to the problems and modelled in the games include time taken to resolve the problem, and the regulatory requirement to fully explore possible root causes of the issue. Assessment was based on student reflections on their experience in game play, and on their team case study writing.

Keywords: Twine, Biochemistry, Forensics, Game-based learning, Case Study method

1. Introduction

People make sense of the world by telling stories. We explain chains of cause and effect by embedding them in explicatory narratives - by telling stories about how things happened. This mode of understanding and transmitting knowledge dates back to oral tradition around the campfire. Iterations of even the simplest games - analogue or digital - can produce engaging stories of what events unfolded and how the end was reached. Creating interesting game spaces in which learners can explore a problem is therefore a powerful tool to help them capture learning in memorable stories.

2. Games & Simulations in science education

There are many reports and studies which describe the use of games and simulations in learning and argue for their benefits(Squire, 2011; Steinkuehler, 2012). Many studies offer examinations of the pedagogic value, the benefits to collaboration (Squire, 2007) alignment with learning outcomes or describe systematic approaches to evaluation of learning games (Mayer, 2012; Smale *et al.*, 2015). There are fewer studies of games in science education. Connolly (Connolly *et al.*, 2012) reviewed 129 papers from 2004-2001 but found only 11 related to games in science education. Out of 300 papers, Young (Young *et al.*, 2012) saw "little support for science-based serious gaming was revealed" A recent systematic literature review (Kara, 2021) out of an initial pool of 217 articles from the Web of Science identified 39 where full availability of the text allowed exploration of the studies. The bulk of the studies dealt with Experimental science, Biology or STEM education in general with only one specific to Chemistry. Most games were simulations of lab experimentation, and few aimed to improve 'scientific awareness skills', 'self-evolution', 'problem solving awareness' and 'interaction' which were key benefits of our approach. Of the age groups in the 39 papers reviewed by Kara, 10 dealt with primary age learners, 11 secondary and 6 undergraduate with 9 not indicated. This is a similar pattern to other systematic studies of game use in science education (Li and Tsai, 2013; Cheng *et al.*, 2015; Arici *et al.*, 2019) .

More recent literature includes some studies on serious games in science, but it remains limited. This shortage of reviews on games and gamification is pointed to by Kalogiannakis. Gamification, the subject of their systematic review is quite different to serious games but the literature does point to common ground in areas like improving “engagement joyfulness and motivation” and encouraging students to be proactive and reducing fear of failure (Kalogiannakis et al., 2021). A systematic review by Assaf et al also looked at adoption of game based learning in secondary schools, noting that early promises of easy adoption were unfilled and looking at issues with teachers, institutions and technology which affected adoption (Assaf et al., 2021). Liberona et al offer a recent broad survey of game based learning, gamification and serious games in the wider context of technology developments in higher education, with a particular case of entrepreneurship education (Liberona et al., 2021).

Interesting individual studies continue to focus on secondary level education. In reconciling game design methods with learning design in STEM games, a base narrative from a chemistry textbook was used to test a formal model of multiplayer serious game development based on activity theory, linking Goals, Feedback and Interpretation to extend the classic Mechanics-Dynamics-Aesthetics Game design methodology to create a framework linking instructional goals, game mechanics and learning activities. The study dealt with secondary school chemistry, and engaged with teachers as designers rather than students as learners (Garneli et al., 2021) A Danish study to develop elementary students understanding of molecular studies in chemistry was designed in Unity 3D, but the actual student work was done in a 2D, not 3D workspace showing the value of using lower tech for serious games in STEM. Gameplay time was about 20 minutes which aligns to the play time in our work (Bjørner et al., 2021). In a Malaysian study involving 138 students, those using a serious game on chemistry learning outperformed a control group. Like many other cases, this study used secondary level students but unlike many others it did stress aims beyond disciplinary learning including collaborative skills and improving technological literacy (Lay & Osman, 2018).

There is a gap in studies on the use of games at graduate or professional education levels which we begin to address here. There is a lack of games which go beyond simulations to explore problems where the cause-and-effect narrative is more complex. We use Twine as tools to build games which address these gaps.

3. Twine

Twine is simple, graphical tool for creating interactive fiction. Originally designed to simplify the creation of hypertext interactive fiction stories, it has become popular for creating branching path games. The precursors of this genre include Fighting Fantasy gamebooks, and text-based adventures like the original MUD and the Infocom text adventures. Twine was developed by Chris Klimas and first released in 2009 (*Twine / An open-source tool for telling interactive, nonlinear stories*, no date). It became successful when it was taken up by the interactive fiction community. (Ellison, 2013) Current versions include support for JavaScript and, importantly, a visual editor which simplifies the editing process.

4. Biopharma industry in Cork

The Biopharmaceutical industry is an important employer in the Cork region, Ireland. This industry has a long history in the region, and now includes world class R&D as well as production facilities employing thousands of skilled graduates. A new postgraduate diploma programme at University College Cork has been developed in collaboration with several industry stakeholders in this field. This programme has been identified as of key importance for these companies in future proofing of graduates to meet priority skills needs in bioanalytical chemistry for these sectors. This initiative links strongly to Regional development and NDP/Project Ireland 2040 objectives, in particular strengthening relationships with enterprise. Partnering with industry in the design and implementation of the programmes as well as in the development of new innovative methods of teaching delivery such as virtual gaming has been a huge success. In particular, this paper will focus on the novel approach adapted to integrate industry scenarios into virtual games that are aimed at developing and enhancing problem solving and troubleshooting skills. This has been an excellent example of how industry and academia can work together to promote an industry-relevant teaching agenda and secure funding through the Human Capital Initiative (HCI) and deliver such a bespoke programme.

5. HCI initiative

A key aim of government policy has been providing graduates with the appropriate skills to support the continued growth of industries. As well as supporting STEM education at third level, there have also been initiatives like Springboard and the Human Capital Initiative which have specific, identified needs in the workforce. These initiatives fund the development of new programmes which are aimed at filling gaps identified by labour force surveys and industry consultations. The HCI funds new courses which are designed with industry input and participation.

The Postgraduate Diploma in Bioanalytical Chemistry is one such course. Industry partners involved in developing the course, and who deliver expert guest lectures and seminars include, MSD Brinny, Pfizers, Janssen, BioMarin, Regeneron, Eli Lilly, Thermofisher and Agilent. Several of these companies have collaborated in the design and development of virtual games based on industry scenarios that they have put forward as pilot case studies. These scenarios have been specially designed to complement the lecture material in the modules delivered as part of the Bioanalytical programme so that the student can leverage the knowledge base in the curriculum and apply it to playing and solving these scenarios in the format of a virtual game. A dedicated module was established to host these scenario-based games and provide a specific opportunity to assess problem solving in the overall context of the programme as the games span across multiple modules.

6. Industry case studies

The ownership of the case study method has been vigorously asserted by Harvard where it is traced to the School of Law in the 1870s and the Business School from 1911 onwards. In the Business school version, businessmen were invited to present a problem from their experience to the class and answer questions on it. The students then wrote a problem analysis paper which was critiqued by the business expert (Kimball, 2009). (DeLacey and Leonard, 2022) Whether they invented the method or not, this description is relevant here as this module drew on real world problems in the industry to design learning games for the students.

A key element of this module is that the problems which the students explore are predominantly based on real world problems encountered by the industry parties in their actual work. Cases were mainly written directly by industry partners, with some created by course team members based on knowledge of industry cases. The industry partners were invited to prepare case studies describing actual problems from their experience and outlining how those problems were solved. In most instances, the case studies were vetted by the firm's legal affairs teams to ensure no commercially sensitive information was revealed. This slowed the process but was necessary to allow for the release of the games to students and the possible release of some games as open educational resources.

The course team were already enthusiastic advocates of game-based learning. In order to bring industry partners onboard, it was necessary to host a seminar for them introducing game-based learning, interactive fiction games and Twine in particular.

The ease of use of the graphical editing environment in Twine was a key enabler in this process - while industry representatives grasped the general idea of game-based learning, it was the immediacy of an interactive demonstration of Twine which enabled them to translate their understanding into practice. The Twine demonstration was important for many industry partners in understanding how to 'chunk' problems into meaningful blocks in writing their case for students. This allowed them to view these cases in a new light and see the components of the problem and solution in a new way. It also meant that the cases studies as written were presented in a well organised way which made conversion into Twine games much faster.

The case studies presented by the industry partners included several elements about and beyond the core bioanalytical chemistry problems. In real world production, time and resources are often critical in determining the case of variances and resolving them. Thus, for example it might be necessary to track time taken to resolve an issue. For example, it might be essential to resolve a problem within 40 days. The investigative options at each step may take different amounts of time, and the games presented the learners with a choice between tests which might only take 1 day, or which might require 3 or 4 days. In some cases, the quick answer was the correct path to gaining more information towards a solution, but in others it was not, and time could be wasted by making a poor choice of investigation. (How this was tracked will be discussed below...)

7. Example of a Twine Game Screen

Example 1 - in the example the correct way to progress is option 2, although Option 3, since it saves time, is superficially attractive but incorrect

Question 2 : Breakdown the problem
You have discussed with your manager that in your opinion the priority is to identify the root-cause of the high oxidation values. Your manager mentions that the lab is under severe time constraints due to multiple projects ongoing simultaneously and asks you for more details on the problem to assess the criticality and urgency to solve this investigation.
What do you reply to your manager? Select the correct answer
Option 1: The origin of the samples is not critical, and you do not want to delay the start of the investigation since finding out these details will take 4 days. The important issue to resolve is the high oxidation values reported since it might re-occur in the next samples (4 Days)
Option 2: 2-You do not have enough information to answer the question fully. It is a priority for you to obtain this information, but you would need to go through the 4 W's process (who, what, when and where) first, although this process could take some time (4 Days).
Option 3: 3-You mention to your manager that you do not believe that the issue is related to the analysis. You have done preliminary research and have read that the levels of dissolved oxygen in the culture and culture temperature are known to be a major contributor towards oxidation. Since you have not encountered issues in the past with

similar types of testing, you anticipate that issue could have occurred during the cell culture process. You therefore do not expect that the investigation will involve many QC resources which are needed to support the other ongoing projects. (1 Day)
Days Taken: (2)/ 40

Equally, resources are not infinite. The learners progressing through the games could not expect lab tools or specialists to be at their beck and call in the real world, and they had to make choices based on the availability of those resources.

Other human factors were also presented in some of the cases. Work colleagues might not return results or information promptly because they were uncommunicative or unresponsive for various reasons. In some cases, these might have nothing to do with the workplace - health, or illness of a family member for example. Modelling them into the games meant players faced choices about how to deal with human issues and handle interpersonal problems in the workplace which affected the outcome of the investigation.

8. Root Cause analysis

The BioPharma industry is subject to strict regulatory controls, and one aspect of these is a requirement that any variances be comprehensively investigated. It is not sufficient to find an answer to a problem, it is also a requirement that the problem be fully investigated to exclude the possibility of any other contributory factor. The key methodology here is called "Root Cause Analysis". This is visually represented as a 'fishbone' diagram. To coin a phrase, it is necessary to fully bone the fish. Industry also applies the 5 why principle to determine the root cause of a problem. This is a very simple and effective approach to establish the origin of the issue being investigated and is used to prevent this issue from occurring again in the future.

9. Assessment

Assessment of the game play part of the module was based on student reflections on the game play. Students were not required to complete the games, but they were expected to progress though about 80% of 2 or 3 of the 6 games available to them. Ideally students would cover enough of the game content to satisfy the requirement to explore and eliminate possible alternative causes on the 'Fishbone' They were then asked to write a reflection of 500 words on their experience and what they had learned from the games.

In the second part of the module, students were formed into groups of 3 or 4 and asked to write a case study suitable for conversion to a Twine game. Students were shown Twine in the same way as the industry contributors had been, to assist them in creating structured case studies. Students were not expected to build their cases into a Twine game, but one group did produce a successful Twine game and one other attempted one. While most groups submitted their work as word documents, one also supplemented this with a limited decision tree.

Student cases were shorter and simpler than the industry cases. Groups which included students with more industry experience produced case studies which were broader and more challenging while groups which counted less work experience in their membership produced cases which were shorter and focused more on the science of the problem and less on other aspects of real-world production issues. Students reported that they found writing the case studies challenging. They particularly found it difficult to imagine a credible or interesting problem as a basis for the cases.

Grading overall for the module was a simple pass/fail and students who completed the required number of games, wrote a reflection, and contributed to the group case study writing passed. A key goal of the module was to expose students to real world problems, encourage critical and innovative thinking and develop skills in collaborative knowledge work in the domain.

10. Coding in Twine

Twine has two main story formats, Harlowe and Sugarcube. Harlowe is the easier of the two to use and most beginner friendly with significant built-in functionality and requires very little experience with code. Sugarcube has less functionality but can create a more varied and graphic heavy game. Snowman is also used as an advanced story format. Harlowe was the best in choice to make the games as reproducible and sustainable as possible.

In contemporary game development, accessibility with poor connectivity is something that is sorely lacking both in mainstream games as well as in game-based learning in academia. An aim for this game was to create something that was as accessible as possible for the work-from-home environment that was prevalent at the time of the creation of this project. The fact that Twine games are published to simple HTML files allows for them to be run on all levels of device and allows them to be self-contained and with a little work, completely independent from Wi-Fi. These games had very few graphics and graphics that were included were converted to base64 and embedded in the .html file to avoid the need for zip files to send out the students. The only aspect of these games that was dependent on internet connectivity was the data collection at the end. Using the history macro throughout the game and variable tracking the student could complete the game and collect their results without the need for an internet connection.

In one of the case studies, there was a time limit of forty days for a resolution to be found. To track time taken students stayed within the forty days, the variable '*$days*' was added, and each option had a certain amount of time attached to it. So, an answer may take one day or take eight days, students would choose the answer and depending on the amount of days assigned to it their day counter would change ('?/40'). If a student chose the wrong option, they would still lose that number of days to show real-world consequences for incorrect decisions. Some graphic effects and aesthetic elements may be added to make the student more aware of the passage of time such as colour changes in the days counter as students approach the deadline.

Thus at start the variable $daystaken was declared and set to 1

```
(set: $daystaken = 1)
1. You have 40 days (in game) to identify the root cause, most options will
have how many days it will take to execute the action assigned to it
```

The variable was incremented based on the students' choices as they moved through the game. Here it is incremented by 1 day:
(set: $daystaken += 1)

(text-colour:red)[''Incorrect, you have lost a days work'']
''Reason'' : : without knowing the origin of the samples, you might exclude the right stakeholders from the investigation, who could provide details around the correct root-cause, and you cannot assess the criticality of the investigation
[[Go back -> Question 2]]

This example also shows an incorrect choice, styled in red, and offers the option to go back and try again.

Student pathways were captured with the history macros; you can also track macros as variables (*Is it possible to track the path of users through a branching scenario? - Twine Q&A*, no date) This was tested but required cross-domain permissions to a Google sheet. In future versions pathways will be tracked via the history macro. Students will then have the option to see the path they took through the game. This will also be of value for the lecturer to see the path they took and how it links to the reflection they write about their choices in game. At the end of the game, students can be presented with the pathway they took using the history macro. This pathway listing was not as clean as it could have been due to the naming conventions of the passages which were chosen to produce cleaner back-end code.

Ensuring the players adequately explored the root cause fishbone was controlled with a variable, $fishbone. Each key aspect, new revelation or piece of information was tracked by incrementing the variable $fishbone when they visited that passage in the game. There were also random points within the fishbone that were not required for the final answer which were counted with the variable $misc to ensure that students had adequately investigated the subject to the full extent as they would have to do in a real-world situation. The final passage in the game would only be revealed once the $misc and $fishbone variable had reached a certain number. This was necessary as in many real-world examples there would be multiple routes to the resolution of the investigation so the pathways had to be marked.

Here then we see the fishbone variable is initialised at game start:
(set: $fishbone = 0)

And incremented after the student has visited a branch of the fishbone
''Decision: YES to review the potential for Leaky bags''
''Outcome'': Luckily the bags are still in the area awaiting disposal, you perform a visual inspection and determine there was no leak – no assignable cause
[[Back to Materials -> 600]]
(set: $fishbone += 1)

Here we see the main switchboard passage of the fishbone, and at the bottom the code to allow the learner to progress to the final slide if they have visited enough elements of the root cause fishbone diagram (in this case, 14 steps on the fishbone).
''Decision: Fishbone''
- You have gathered together some experts on site to help you to brainstorm possible root causes for the OOS.
''(click on each header to decide which of the potential causes you should investigate next)''

- [[People -> 300]]
- [[Method -> 400]]
- [[Environment ->500]]
- [[Materials -> 600]]
- [[Measurement -> 700]]
- [[Machine -> 800]]

(if:$fishbone > 14)[=[[You have conducted sufficient analysis -> Final slide]]]

Creating a basic inventory in Twine just means creating a variable array. However, because the variables were so basic in these first games this was unnecessary. A development that will be added in later iterations of the games is the variables tracking the choice of specific team members to assist in investigating a problem or specific items in a lab investigation. This will involve more coding for these options, although it would be quite repetitive rather than complex. For example, an individual team member may have certain skills which would allow more options to be seen within the investigation or some team members may hinder the investigation due to personality or skills. Certain items chosen may allow for greater investigation within the game. This would require a full inventory of available lab equipment. Team members who had been chosen by the player to accompany them with the investigation would each need an in-game skills profile defined as an inventory.

For external data collection, the two main options were Microsoft Azure (Emilia, 2021) and data collection to a Google spreadsheet (Stewart, 2018). Microsoft Azure would have been the most useful as it allows for up to a thousand unique interactive online players when hosting a game. Numbers above that require a paid licence so it was not felt to be an option for accessibility and longevity of the project. If an academic institution wanted to use it, it is included within the Office365 licence. The other option was data collection to a Google sheet which requires around 60 lines of code inside of a coded Google sheet and 25 lines of code within the JavaScript in the Twine and on the last passage of the Twine to specify which variables are to be sent to the sheet at end of the game. However, an issue arose with that data collection method due cross-domain permissions with certain browsers.

The easiest route to develop for these games further would be to transfer them to Unity and to increase the interaction and graphics to create a more well-rounded gaming experience. Unity is a mainstream game development tool, but it is complex and not very intuitive. A way to make this type of game development process more accessible in Unity is with the use of the 'Fungus' plugin. Although no longer available from the Unity asset store the GitHub is active and regular updates and patches are released. Fungus is based on interactive narrative tools such as Twine and Yarnspinner and was created to help bridge that gap between the basic branching narrative process of Twine and the high-level game development aspects of Unity. There are also tools such as 'Cradle' available to convert Twine files directly into Unity game bases without the use of Fungus. However, this process can often become over complicated and difficult if you are new to Unity as a tool. Fungus as a tool has built-in functionality and pre-sets to start off building games and the original blog has numerous tutorials and videos on adding extra features such as active inventories, more complex character profiles and text to speech dialogue tools. Currently, we continue to develop these games in Twine as text and 2D graphics means more devices can support the games making them more accessible to students. The plan is to eventually move into parallel development in full 3D realm using Unity to create a high-level immersive gaming experience that will create an active learning environment.

11. Conclusion

This use of industry case studies in branching path games exposed learners to real world problems which include real industry issues beyond the lab including personnel issues, resource use, scheduling and regulatory requirements which are not covered in most simple simulations in the field. Learners were required to explore alternative pathways to solutions, creating learning stories in which wrong turns and backtracking to find the correct solution were important parts of the learning. Having been exposed to this way of presenting problems, learners were then better able to creatively imagine possible problems in the field. They were also better able to break down those problems into discrete issues and 'chunk' them into manageable tasks which could be presented to future cohorts in the Twine game format. The reflection-based pass/fail assessment model encouraged exploration of a variety of approaches to both the game play and collaborative case study creation. This allowed learners space to develop a deeper engagement with the problems.

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