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Glitchspace: Teaching Programming Through Puzzles in Cyberspace

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Abstract:

There is an increasing need to address the player experience in games-based learning. Whilst games offer enormous potential as learning experiences, the balance between entertainment and education must be carefully designed and delivered. Successful commercial games tend to focus gameplay above any educational aspects. In contrast, games designed for educational purposes have a habit of sacrificing entertainment for educational value which can result in a decline in player engagement. For both, the player experience is critical as it can have a profound effect on both the commercial success of the game and in delivering the educational engagement. As part of an Interface-funded research project Abertay University worked with the independent games company, Space Budgie, to enhance the user experience of their educational game *Glitchspace*. The game aimed to teach basic coding principles and terminology in an entertaining way. The game sets the player inside a Mondrian-inspired cyberspace world where to progress the player needs to re-programme the world around them to solve puzzles. The main objective of the academic-industry collaborative project was to analyse the user experience (UX) of the game to increase its educational value for a standalone educational version. The UX design focused on both pragmatic and hedonic qualities such playability, usability and the psychological impact of the game. The empirical study of the UX design allowed all parties to develop a deeper understanding of how the game was being played and the initial reactions to the game by the player. The core research question that the study sought to answer was whether when designing an educational game, UX design could improve philosophical concepts like motivation and engagement to foster better learning experiences.

Keywords: User Experience, Game Design, STEM, Games-Based Learning, Visual Programming

1. Introduction

In the game design and development process it is essential to always consider the player and their experience throughout. The user experience (UX) is key as it is the core characteristic of how the player will interact with the game and if not designed well will frustrate players. Having a clear understanding of the players' wants and needs in a game aids the design and provides focus during the development process. It is arguably more significant to consider the UX in the creation of educational games and games being utilised for games-based learning where engagement has a direct impact. While studies (Kumar, 2013; Mekler et al, 2013; Hamari, Koivisto and Sarsa, 2014) have considered the potential benefits of utilising games as innovative learning experiences there is still a great deal of research that needs to be done on finding a balance between educational aspects and the entertainment properties of a game to keep the user engaged while learning. Successful commercial games can lose sight of the educational aspects and focus predominantly on the entertainment value, conversely games that solely focus on education forget that the engagement of the user suffers due to a lack of entertainment (Groom, 2013; Bakar, Inal, and Cagiltay, 2006). Focusing on the UX of the game *Glitchspace*, the academic-industry collaborative research project presented has value for games developed with both entertainment and education in mind. Specifically, we consider how the UX design can improve philosophical concepts like motivation and engagement to foster better learning experiences.

Games based learning (GBL) is increasingly utilised as a framework for creating engagement, encouraging motivation and developing skills in a range of diverse subjects. Academic researchers and game developers are exploring the potential that games can offer as learning experiences (Groom, 2013). In the creation of educational games there are multiple hurdles which developers need to overcome. One of the most prominent problems is maintaining a user-centric focus during the game design and development process. In the design of games for education (and other games with purpose) the most successful commercial games, such as *SimCity, Plague, Inc.* and *Minecraft*, move the focus away from the educational aspects of the game to ensure gameplay remains varied and entertaining. In doing so games can diminish the educational weighting that they were designed to enhance. In the same vein, games that focus purely on the education aspects can assume that the entertainment value is brought by the content or the process of playing and leave these entertaining

aspects under designed. Gamification has also been shown to demotivate, and lead to less satisfaction, and empowerment (Hanus and Fox, 2015). It is therefore vital to find a balance between both education and entertainment and ensure the player is at the forefront of the design process. This paper examines the game *Glitchspace* and the collaborative academic-industry research project which was used to enhance the games UX to find a balance between entertainment and education. We consider quality as both pragmatic (usefulness and usability of the game) and hedonic (motivation, stimulation and challenge) applying Hassenzahl's model of interplay between the two (Hassenzahl 2004).

2. Background

Games have risen in popularity in mainstream culture with 67% of US households owning a device in which games can be played on and more than 150 million Americans playing videogames in 2017 (ESA, 2017) This increased level of popularity has allowed for games to branch into other aspects of daily life, beyond a means of entertainment, it is now a medium that reaches a wide range of demographics. Evidence suggests that games can be engaging for even elderly users (Zelinski and Reyes, 2009). It has been argued that games are an engaging and motivational medium and one that has several potential advantages and benefits over more traditional means (McGonnigal, 2010; McGonnigal, 2011; Zichermann, 2011). Games drive intrinsic motivation, encourage behaviours that deliver internal rewards like achievement, satisfaction and enjoyment (Deterding et al 2011, Muntean, 2011, Glover, 2013). This is especially relevant when considering how new generations engage with digital media, which despite unprecedented numbers of users has also seen a steady decline in the number of skilled graduates in computing science (Livingstone and Hope, 2011). Various initiatives have been made to encourage interest in technologies beyond those of 'skilled users' and foster a greater understanding in the underlying coding principles that underpin all digital technology. Games do offer potential solutions to problems facing education because they are adaptable at allowing players to set their own level of challenge, can foster resilience through multiple play attempts and provide flexible approaches that let players progress at their own pace. Several studies have indicated that games have a demonstrated ability to improve creative thought (Jackson et al., 2012), multi-tasking (Abbott, 2013), hand-eye coordination (Gozli, Bavelier and Pratt, 2014), enhance perceptual and cognitive skills (Boot, Blakely and Simons, 2011) as well as problem solving (Oei and Patterson, 2014). This re-emergent field of combining learning with entertaining play has been capitalized upon by commercial titles as diverse as *Portal* and *Minecraft Edu*, both standalone educational variants of hugely successful commercial titles or *Metamorphabet*, a game that teaches players the letters of the alphabet, and *TIS-100* a game where the player rewrites corrupted code to repair the TIS-100. Such successes demonstrate not only the commercial validity of the market, but the capacity for the enrichment of the educational experience that games based learning can offer.

However, there remains an inherent challenge in commercial-off-the-shelf games that inevitably design for the market and games designed to educate. Balancing both is necessary to maintain player motivation and engagement. The game development company, Space Budgie, was created with the specific aim of filling this gap by developing titles that do more than solely entertain, and by tackling unexplored or difficult topics through play. The company's first release was the game *9.03m*, an empathy game designed to raise awareness and commemorate the victims of the 2011 Japanese tsunami, and raised over £10,000 for charity. The company next applied their ethos to tackling the gap in STEM (Science, Technology, Engineering and Maths) education through GBL. They created *Glitchspace* a first person, puzzle, platformer game that aimed to provide players with the ability to learn programming concepts through play. The game is set in a Mondrian-inspired cyberspace world in which the player must re-programme and manipulate geometry around them to progress. *Glitchspace* utilises a fictional visual node based programming language, called 'Null', as a core mechanic (see Figure 1).

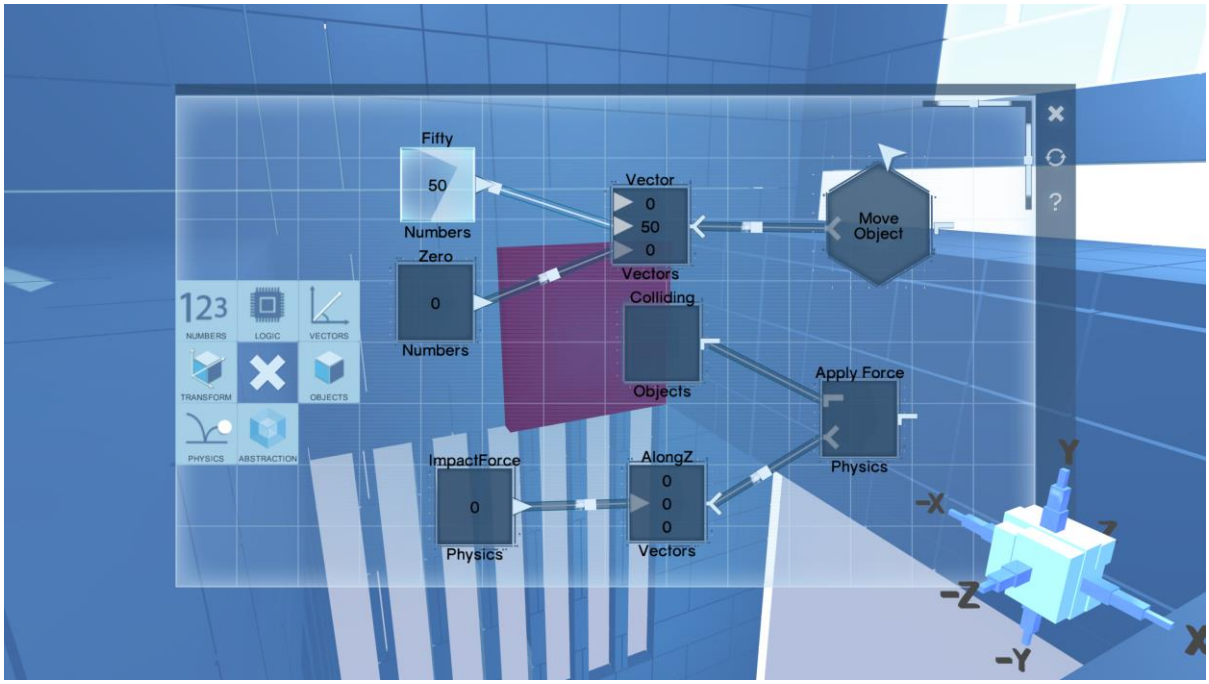

Figure 1. 'Null' Interface

Players discover key programming concepts through the puzzles they solve and can unlock additional functions to craft their own programs in a sandbox mode. The game aims to empower players to use coding as both a means of discovery and in overcoming their surroundings. Starting development in late 2013, the game launched as a paid Alpha in April 2014 and went through multiple iterations before finally being released as a full product in May 2016.

Space Budgies' goals with *Glitchspace* were admirable and ambitious. The game started development amidst substantial social and media attention about the lack of public understanding in computer programming (Wakefield, 2015) and continued debate highlighted gaps in the computer science component of the national curriculum (Livingstone and Hope, 2011), with declining numbers of students engaging with the subject and government interest in STEM increasing (gov.uk, 2014). Initiatives to encourage greater interest and participation in coding and computing in general, such as the 'Raspberry Pi' also gained traction throughout *Glitchspace's* development. If the idea appeared sound and had market potential, the game itself was harder to design. Early prototypes focused on a programmable gun that could fire out programs into the games world, (see Figure 2). These prototypes evolved but the core ideas served as the basis for the Alpha version. *Glitchspace* made its debut at GDC's Experimental Gameplay Workshop sessions in 2014, subsequently releasing on Steam Early Access in April that year.

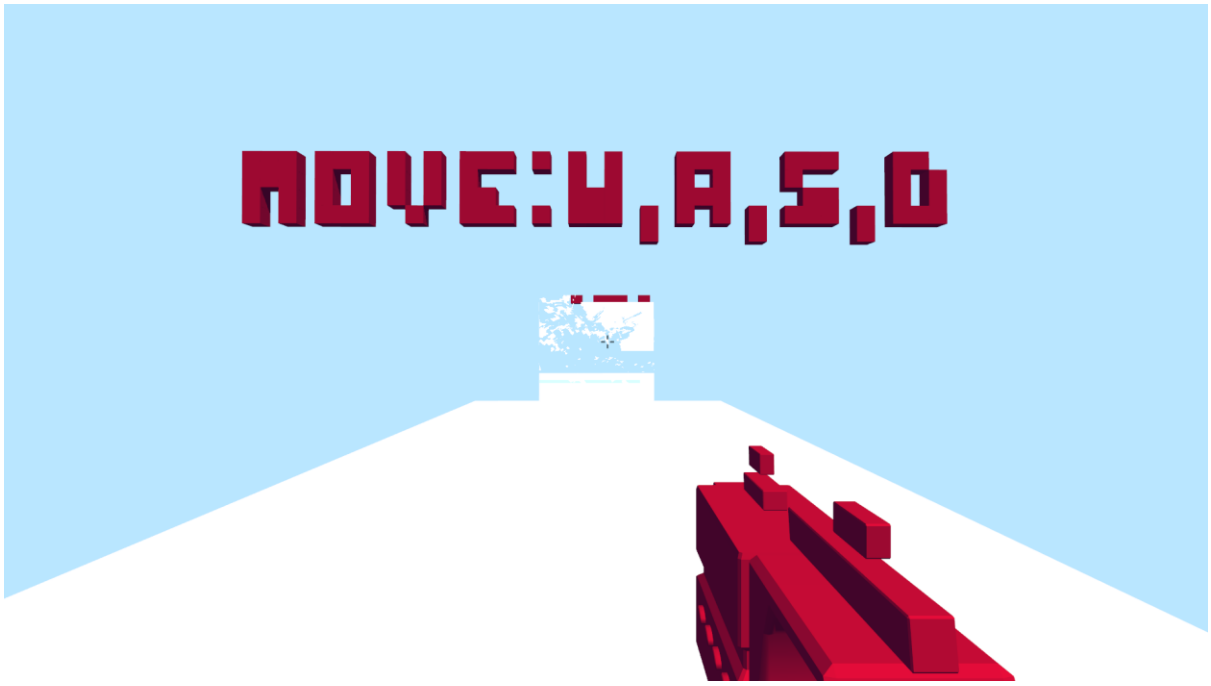

Figure 2. Early Prototype with Programming Gun.

Early reviews were promising with major press outlets including *The Guardian* (Stuart, 2014) and *Wired* (Clark, 2014) praising the commercial innovation, and industry outlet *Eurogamer*, stating that it "looks unique, bewildering and promising" (Matulef, 2014). *Gamespot* also highlighted that it "could become one of the more inventive puzzle games to arrive on the PC in some time (Todd, 2014). The idea for an academic-industry collaboration between Space Budgie and Abertay University was the result of international interest in the game from the educational sector and one institution's order of units for classroom use as part of their computer science programme. Whilst the development team were confident of building an entertaining game they looked for academic and educational expertise to ensure that learning objectives could be met effectively in-game. The aim of the collaboration focused on harnessing the games potential to develop a standalone educational version of *Glitchspace* for use in primary, secondary and tertiary educational sectors as a classroom learning tool for the computer science subject. To achieve this the collaboration centred on redesigning the games user experience (UX) to maximise its educational value. In early 2015 the decision was made to redevelop and re-design some of the gameplay, user interface and user experience to enhance the educational aspects. An iterative model was utilised to test with different Educational institutions (primary, secondary and tertiary) and allow time to implement changes. How this iterative approach shaped the user experience was fundamental to the pragmatic and hedonic quality outcomes.

3. *Glitchspace* UX Design Process

Several different models of game and user experience analysis were considered before determining on a heuristic design approach together with an empirical study of how an iterative approach improved engagement (Zaharias, Gatzoulis & Chrysanthou, 2012). The study focused on pragmatic (usefulness and usability of the game) and hedonic (motivation, stimulation and challenge) quality for the user, adapting Hassenzahl's model to the project goals (Hassenzahl 2004). Initial plans to implement more detailed in-game analytics were dismissed due to both budget cost and the additional development time required. Evaluation was undertaken through a mixed methods approach of quantitative questionnaires with qualitative observation of players. The collaborative project was planned into four distinct stages: Scoping; User & Focus Testing; User Experience Testing and Evaluation.

The first stage was a cognitive walkthrough of the game identifying potential issues for a new user. This informed the development of the test planning and user questionnaires, the latter focused on statement based questions and used a Likert scale. The questions centred on the UX areas: Usability/Functionality, Accessibility and Enjoyment. These areas were subcategorised for User Interface, Learnability, Motivation and Aesthetic. This provided quick quantitative feedback to the development team and was supplemented with

qualitative observation to determine UX problems encountered during play testing that the questionnaires may not reveal. The second stage centred on focus and usability testing to iterate on prospective features and new design elements. Testing examined the pragmatic quality of the *Glitchspace* UX; what introductory programming concepts users could comprehend and learn effectively and those which they were not. The rapid development process further refined the visual programming mechanic, and acquired a range of qualitative data to compare and analyse. A range of user and focus testing sessions from specific one-to-one sessions to a large scale public event were used to acquire the necessary data. For each session users played through the same version of the game, ensuring a strong baseline. The next stage built on the previous results to examine the hedonic quality and concentrated on more detailed user experience testing. This stage was conducted with two core user groups of approximately twenty tertiary education students in each, and supported by additional focus group testing with secondary schools. The fourth and final stage re-assessed and evaluated the project goals to determine whether the iterative model was successful in improving motivation and engagement to foster a better learning experience. It is worth stating that during the process it was clear that many design changes to improve the educational aspects were rolled into the commercial release, in part because they worked but also due to the need to limit the impact of delivering and maintaining two versions on a small team.

4. *Glitchspace* UX Quality

The pragmatic quality of *Glitchspace's* UX was initially evaluated during the first round of user testing, where multiple users from different backgrounds and demographics played through the Alpha build. This was critical in helping to determine the key demographic user groups and how various demographic groups performed while playing the game. In total data was collected from 155 participants (8 one-to-one sessions, followed up by 147 over 4 days of a public event). Ages ranged from 6 years to 61 years of age, with over half of the participants aged 14 and younger. The gender balance was reflective of the public event with 80:20 male to female ratio. In terms of education 70% of player were from primary, secondary and tertiary education sectors. Overall the initial feedback was very positive and demonstrated the pragmatic quality of the game design. The quantitative results indicated a very positive attitude towards the game, with more than 90% of the total users agreeing that they enjoyed playing the game and wanting to play more. More than 70% of participants stated that they understood the tutorial instructions and over 75% of users agreed that *Glitchspace* felt like an educational game. In terms of educating 80% felt they understood the terminology and concepts presented to them in the game, and solutions to each puzzle. However, when asked if they understood more about programming this dropped to just over 60%, the lowest percentage of all the questions. In terms of usefulness and usability the game design would appear to be strong. However, the observational notes indicated that most players struggled with the tutorials requiring guidance to progress. Similarly, the discrepancy between understanding terminology and core concepts versus programming demonstrated that users could learn how to play the game without necessarily absorbing the deeper knowledge behind their interactions. Overall the real value in determining the pragmatic quality came from the observation of users. These identified significant problems with the UX, most notably in the areas of user interface; visuals; learnability; and motivation.

The hedonic quality was largely tested in the third stage of detailed user testing. This testing focused on three main aspects: engagement, motivation and learning. Engagement measured the amount of time players engaged per session, number of puzzles solved and how often they returned to the game. Motivation examined how players interacted with the design and how they set about their goals and in solving puzzles in different ways. To understand whether the learning objectives were successful in each testing session players with little to no coding skills were analysed how well they retained the core concepts. To improve these the project team focused on four key areas of the game:

- Art Style: *Glitchspace* did not look or feeling like a traditional educational game. This helped retain player engagement and focus on puzzle-solving.
- Tutorial: tutorial animations and imagery were initially unclear, players did not know what to do at start of the game, and were confused at the beginning of the game.
- Motivation: Lack of feedback or reward on completion of puzzles. Users often struggled to know if the puzzle was solved or weren't aware when to move on.
- User Experience: improving many minor usability, accessibility and minor cosmetic issues combined to create a stilted user experience that restricted flow and immersion.

With each iteration the team could improve these features to reduce friction points and enhance both the pragmatic and hedonic quality. The final internal evaluation of the game, prior to full commercial release, demonstrated that the game experience ran well and was very polished, there were no major issues that affected the user experience. However, there were still minor issues that were either aesthetic related or required additional clarity of information. The game delivered on the core values and the project goals, and formally released in May 2016.

5. Market Evaluation and STEM Engagement

In determining the success of the UX design ultimately any commercial product is judged on its sales. *Glitchspace* was relatively successful for a small indie game, with some 16,000 sales. Unfortunately, it never achieved the return that was anticipated. Once the company factored in the sales made in early access, most of which were made at lower price points and all of which had been fed back into development, the game could not sustain the development team. The intention of the academic-industry collaboration had been to build on early interest and success to create an entertaining and distinct educational product. The aim was that *Glitchspace* would, in turn, encourage engagement with STEM based subjects among its players. This has already been shown to work with iD Tech summer camps adopting the likes of *Portal 2* and *Minecraft* to aid in teaching the fundamentals of STEM subjects such as maths and physics (Gera, 2013). In the end the decision was made to develop and maintain a single *Glitchspace* product. Whilst a standalone educational product may have opened distinct market opportunities it would arguably have distracted the development team from its core vision to tackle unexplored and difficult topics through play. Pursuit of the vision was key to the critical acclaim the game received but ironically may have hurt sales to a purely educational market. For Space Budgie sales were not the single measure of success, and whilst the ambition and vision undoubtedly contributed to the protracted development cycle of *Glitchspace,* they were ultimately rewarded with positive user reviews and critical acclaim including a British Academy Scotland Award (BAFTA). Indeed, the game currently sits with a Very Positive (82%) rating on Steam and a critical analysis of the user feedback indicates that many of the negative reviews focus on common complaints in many game reviews such as the game length and perceived repetition/challenge of the puzzles. The positive reviews give a clearer indication of how the game achieved its core aims and objectives. As one player described it “I've seen a fair share of games give said player the ability to "code" certain block or areas to let you progress further in the game, but I've never seen a game such as *Glitchspace* do it so well.” Others praised the game as a “nice little game to get introduced into the world of object based logics with visual programming” or “a great game to get introduced to simple programming logic with.” (Glitchspace on Steam, 2017). Perhaps the success of the user experience is summarised by two comments one which described Glitchspace as a “Phenomenal tool for learning basic underlying logic for programming in fun way; my 8-year-old took to it immediately. Beautifully minimalist artwork.” (Store Curator: Designer plays, 2017). The other that emphasises that the games core values and concepts were applied successfully with the player stating:

> “As a programmer, the game mechanic's [sic] were awesome. I love interesting game mechanic's. The game was a decent representation of coding and its obstacles. In this game it is literal obstacles that you overcome. If you even have the slightest idea if you would be enjoy coding, try this game out. I could see this as a great way to learn basic logic to solve problems in a fun manner with out [sic] the overhead of actually learning a coding language.”

The feedback on Steam was reflective of the project team’s experiences in examining the game’s effectiveness as an educational tool and as a means of encouraging STEM engagement. When *Glitchspace* was taken to gaming events (in addition to educational institutions) the results were immensely positive when players connected with the game. One of the most interesting developments was the game allowed pupils and teachers to discuss and share ideas regarding code and STEM in a more informal manner, especially regarding the role of computer games in the classroom and what they feel would encourage interest in STEM subjects. One of the challenges for STEM engagement is that although games are becoming more popular as an educational tool, the facilities are not always available, particularly within primary schools. The projects experiences indicate that entertaining games can clearly engage students in areas that they may have had little initial interest in but arguably there needs to be more to this initial experience to support both students and teachers. The success of other games (like *Minecraft Edu)* are partly due to the greater breadth of content and learning ecosystems available. For *Glitchspace* there is arguably more value in participatory design or co-design

projects where students can engage in workshops with specific learning objectives. Arguably adding Steam Workshop support may have helped *Glitchspace* in this regard but was another feature too far. It is worth noting that *Glitchspace* did much to achieve its objectives by educating through stealth. For pupils and students, the fact that *Glitchspace* did not feel like it was an educational game was important in creating a desire to continue playing! The project did deliver improved UX but determining player retention, and motivation remains challenging.

6. Conclusion

Glitchspace demonstrates both the advantages and disadvantages of academic-industry collaboration and the inherent challenges in games based learning. The project demonstrates that applying additional attention to the UX design could improves philosophical concepts like motivation and engagement but the gain is marginal in comparison to initial good design. The positive response of players does indicate that these do foster better learning experiences, but measuring success remains challenging. For Space Budgie the collaboration enabled the development team to receive frequent unbiased feedback relating to the usability and accessibility of their game. This enabled the small team to remain focused on the development of features to enhance the user experience but also to create a product that was superior and had access to a much wider market at launch, than planned. The ability to improve the educational aspects of the product through targeted testing also helped to show the true value of this product to potential investors not just an entertainment item but also as an educational tool. For the University, the collaboration allowed Abertay to accumulate a large set of qualitative and quantitative data through the organised focus and user experience testing of the game. The project has set the groundwork for other collaborations and further educational and training projects with a range of diverse industries, including aerospace design, police training and intellectual property theft. The initial data gathered can be further utilised for case studies and expanding on on-going research at the university relating to game-based learning, non-traditional methods of teaching and games with purpose. However, the lack of post-release data also demonstrates the need for embedding analytics as core for measuring success.

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