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Mission to Mars
An Educational Board Game

MISSION to MARS

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Abstract:

This dissertation covers the stages involved in creating an educational board game for year 7 (Y7) students, which aims to increase engagement and uptake in STEM subjects. The report discusses background research, project planning, concept development, design ideation and product testing that was conducted to create the game. The game is titled 'Mission to Mars' and teaches students about physics, astronomy and other aspects of science, whilst also developing their wider skills. It should help students develop communication, teamwork, leadership and problem solving skills and increase their enthusiasm for science.

Key Words:

Key Stage 3, Year 7, Education, Curriculum, Gamification, STEM

CONTENTS

1.0 INTRODUCTION 1-2

2.0 BACKGROUND RESEARCH 3-20
- 2.1 The Science Classroom 4
- 2.2 The Curriculum in Wales 5
- 2.3 Teacher Interview 7
- 2.4 Why Use Educational Games? 8
- 2.5 Team Based Gaming 9
- 2.6 Market Research 10
- 2.7 Analysis of Educational Games 13
- 2.8 Competitor Analysis 15
- 2.9 The Target Market 17
- 2.10 Board Game Design 19
- 2.11 Considering Alternative Game Styles 20

3.0 DEVELOPMENT PROCESS 21-25
- 3.1 Design Brief 22
- 3.2 The Project Plan 22
- 3.3 Product Specification 25

4.0 BRAND DEVELOPMENT 26

5.0 MATERIALS AND MANUFACTURING 27-29
- 5.1 Materials Research 28
- 5.2 Material Choice 28
- 5.3 Manufacturing and Printing 28
- 5.4 Environmental Impact 29

6.0 GAME DESIGN 30-50
- 6.1 Game Concept Research 31
- 6.2 Game Concept Development 32
  - 6.2.1 Game Play Analysis 32

6.2.2 Potential Game Issues 37
6.3 Design Research 39
6.4 Design Ideation 41
6.5 Graphic Design Development 43
6.5.1 Font selection 43
6.5.2 Card Development 43
6.6 Game Reward System 44
6.6.1 Reward System Theory 44
6.6.2 Reward Ideation 44
6.7 Final Game Design 45
6.8 Additional Design Aspects 49

7.0 TESTING AND DISCUSSION 51-54
7.1 Play Testing 52
7.1.1 Session 1 52
7.1.2 Session 2 52
7.1.3 Session 3 53
7.2 Game Balancing 54
7.3 Game Adaptations 54

8.0 CONCLUSION 55-56
8.1 Future Work 57
8.1.1 Second Game in Series 57
8.1.2 Third Game in Series 57
8.1.3 Open Source content and Website 57
8.1.4 Application Support 58
8.1.5 Work and Achievements Book 58

9.0 BACK MATTER V-XXXVIII
9.1 List of Tables and Figures V
9.2 References VII
9.3 Bibliography IX
9.4 Appendix XV

BUSINESS PLAN 59

1.0 INTRODUCTION

This dissertation looks at the problems of engagement and elective study in STEM education, seeking to take a novel approach to help address this through gamification of curriculum content.

Education is a compulsory aspect of childhood in the UK, something everyone has in common, no matter their ethnicity, socio-economic background or other experiences. Education is a devolved responsibility of the national governments around the UK (Gov. uk, 2013), leading to growing divergence between delivery and funding in England, Wales, Scotland and Northern Ireland.

There are currently 4,168 secondary schools in the UK, around 200 of which are in Wales. There are just over 780,000 primary and secondary pupils in Wales and approximately 43,500 teachers (British Educational Suppliers Association, 2018). The education industry is one of the top ten UK industries (Prime Office Space, 2014), figure 2 gives more information on the estimated market value and size.

Figure 2 Education Industry Statistics (IBIS World, 2018)

Although every UK school child must reach set standards of education this does not mean their abilities are identical. It is important to understand

Figure 1 Children enjoying a board game together (Hip2Save, 2018)

and implement teaching appropriate for the different learning styles of individual children, as this can lead to overall higher student achievement and the increased variety of students in a classroom, creating a versatile learning experience for all (Reiff, 1992).

The initial project proposal is to create a resource that will assist with the development of a more skills-based approach to science education in Wales, in the hopes of increasing interest and engagement. The project will be titled 'Mission to Mars' and covers all aspects of the Key Stage Three[1] (KS3, years 7, 8, & 9; ages 11-14) science curriculum, in addition to linking to other subject areas. The intention is to create a classroom tool that assists teaching mixed ability classes, and students who all learn in different ways.

The teaching tool will be a game, using the theme of Mars exploration to help reinforce aspects of the KS3 science, technology, engineering and maths (STEM) curriculum.

This project aims to help create a thematic approach to education in Wales, by designing a game-based process of learning, suited to a wide variety of students and learning styles. In recent years there has been a shift in educational aims, moving away from facts-based teaching and learning towards creating students with a wealth of skills, desirable to employers (BBC News, 2014). The Welsh Curriculum will be updated in the 2020-2021 academic year (O'Neill, 2017), based on an independent review of curriculum conducted in 2014 by Professor Graham Donaldson[2]. The key outputs of the Donaldson Review are summarised in section 2.2, but essentially the emphasis is on a more skills-based approach to education.

The final game should fit in with the pupil's current studies in KS3 science, either as a teaching or revision tool. A key aim behind the project is to increase interest and engagement within STEM education in KS3 pupils and beyond. However, in line with conclusions of Donaldson (Donaldson, 2015) there is also a desire to promote skills, including, (but not limited to), teamwork, problem solving, leadership and communication. To ensure this the author will be working with the School of Physics and Astronomy (PHYSX) at Cardiff University, Cardiff Commitment[3] and Mrs Angela Darke (Head of Science, Cardiff West Community High School), providing access to the proposed KS3 curriculum for science lessons in Cardiff's secondary schools.

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[1] Key Stage 3 (commonly abbreviated KS3) is the legal term for the three years of schooling in maintained schools in England and Wales, normally known as Year 7, Year 8 and Year 9, when pupils are aged between 11 and 14.

[2] Professor Graham Donaldson a former teacher, headed Her Majesty's Inspectorate of Education (HMIE) from 2002-10. He radically reformed the approach to inspection, combining external accountability with self-evaluation and capacity building. As chief professional advisor to Ministers on education, he has taken a leading role in a number of major reform programmes (The Royal Society, 2017).

[3] The Cardiff Commitment is a vision that the public, private and third sectors will work in partnership to connect children and young people to the vast range of opportunities available in the world of work. Ultimately, the goal of the Cardiff Commitment is to ensure that all young people in the city eventually secure a job that enables them to reach their full potential whilst contributing to the economic growth of the city (Invest in Cardiff, 2018).

2.0 BACKGROUND RESEARCH

2.1 The Science Classroom

In the UK there is a tendency to separate students into 'sets', based upon their assumed level of academic achievement (Sellgren, 2017). However, in high achieving educational systems (e.g. Finland, Japan, Canada) mixed ability classes are common (Crehan, 2016), causing a rethink in UK schools, changing ideas on how all students can be intellectually stimulated (Seeber, 2017). Using sets (or 'streaming' students) can have negative effects on those considered middle or lower attainers (Seeber, 2017). They are also effected when set tasks that have right and wrong answers, where results can be directly compared and pre-conceived ideas about intelligence levels can be reinforced (Seeber, 2017).

UK schools that have shifted to a mixed ability class environment have found it to have a positive effect on students, even giving confidence boosts to lower level attainers when they find themselves understanding concepts quicker than those considered to be academically high achieving (Seeber, 2017), while higher achievers are encouraged to learn with more depth, rather than breadth (Seeber, 2017). When it comes to science specifically, there are often no right and wrong results to begin with, creating a diverse subject that requires an array of skills, where no single student is 'the best' or 'worst'. (Seeber, 2017).

It has been shown that at the KS1 and early KS2 levels of education smaller class sizes positively affects behaviour and academic achievement, but this diminishes in impact in later years (Department for Education, n.d.). This has led to legislation on UK class sizes, of no more than 30 students per teacher. However, it is suggested these ratios be smaller for subjects that involve practical lessons, including science, as shown in table 1 (Department of Education, 2018).

These guidelines are frequently exceeded, and larger class sizes are often seen in these practical subjects (Department of Education, 2018). There is currently evidence of average class sizes increasing, sometimes to 36 pupils to a teacher in secondary schools (see Fig. 3), possibly due to demographic changes, increase in birth rate and government policy changes (Rhodes, 2017). Having larger classes can lead to resources being stretched, as well as pupils being more easily distracted by others.

Practical Subject	Year	Maximum number of pupils
Science	8-10	26
Science	11-12	24
Science	13-14	20
Art and design	8-10	26
Art and design	11-14	20
PE - gymnasium and assembly halls	8-10	25
PE - gymnasium and assembly halls	11-14	20
PE - playing pitches and sports halls	All years	30
Music, Technology & Design and Home Economics	8-10	26
Music, Technology & Design and Home Economics	11-12	24
Music, Technology & Design and Home Economics	13-14	20

Table 1 Practical subjects and recommended class size (Education, 2018)

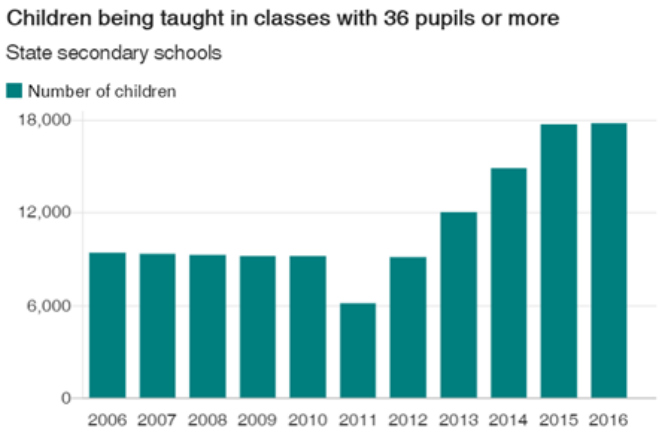

Figure 3 The increase in large class sizes in the UK across a ten-year period (Rhodes, 2017)

2.2 The Curriculum in Wales

In 2014 an independent review of the curriculum in Wales was conducted by Professor Graham Donaldson, titled 'Successful Futures' (Donaldson, 2015). This has led to a significant curriculum reform in Wales, to be fully introduced in the 2020/2021 academic year (O'Neill, 2017). Currently aspects of this new curriculum are being trialled in 'Pioneer schools' across Wales (Darke, private communication).

Key points from the report that the Welsh Government have adopted are that young people need to be enthused about the content, while learning in a way that can equip them for the future whilst still meeting their present needs (Donaldson, 2015). The hope is that the new curriculum will put emphasis on the development of wider skills (Education Wales, 2017), including teamwork and leadership, critical thinking, creativity and problem solving (Donaldson, 2015).

As part of the curriculum update, 'Cardiff Commitment' asked Mrs Angela Darke (Western High School), with the help of Richard Clements[4] (e-learning manager, Cardiff County Council), to outline plans for KS3 Science lessons, that could be adopted by all comprehensive schools in the area and with potential to be used in other parts of Wales. A series of 20 Y8 lessons have been developed (Darke, 2018) which include lesson structure templates and draft resources to aid with this project, examples of which can be seen in figure 4 (and appendix figures 2.1-2.2).

Instead of defining the science and technology curriculum by subjects (i.e. 'biology', 'physics', 'chemistry' etc.) the content is divided into 'What Matters' statements. This has been an important element in the process of designing the curriculum, in order to make it interdisciplinary, and are summaries of the key aspects of the science and technology area (Cunnah, 2018).

[4] Richard Clements works for Cardiff Commitments (a part of Cardiff County Council) as manager of e-learning.

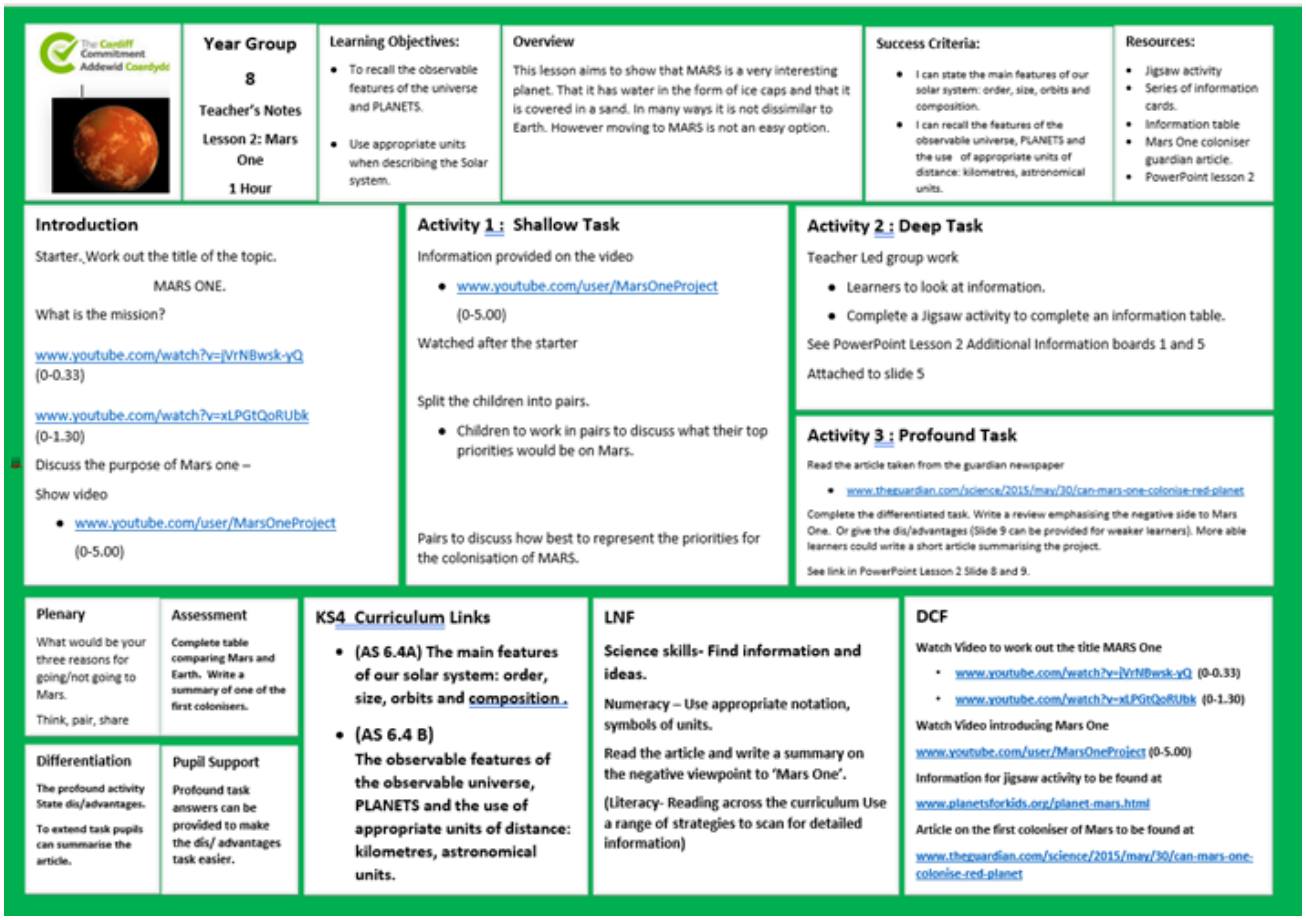

Figure 4 Lesson map for Cardiff Council's new curriculum proposal (Darke, 2018)

WM1 – Being curious and searching for answers helps us develop our scientific understanding of the world around us.

WM2 – Design thinking supports innovation and progress.

WM3 – The world around us is full of living things which depend on each other for survival.

WM4 – Understanding the atomic nature of matter allows us to shape the world.

WM5 – Forces and energy underpin the structure and dynamics of the Universe.

WM6 – Computation applies algorithms to data in order to solve real-world problems.

WM7 – Engineering solutions shape our environment and the way we live.

(Cunnah, 2018)

2.3 Teacher Interview

To understand the new curriculum and what the proposed changes mean for STEM education in Wales the author conducted an interview with Angela Darke[5]. This section summarises the key elements of this discussion - full quotes can be seen in appendix 2.3.

Darke believes these up-coming changes provide a great opportunity to inspire school children with cutting edge science. She is keen to attract more children to STEM subjects as well as developing their general skills. She considers a Mars-themed approach to be a perfect option for students, offering an engaging inter-disciplinary theme.

An important issue raised by Darke, (and her colleagues), is the lack of specialist science teachers at this level – as a biologist herself, she has been teaching physics for twelve years. This has led her to teach all the sciences in tandem, bringing them together in practical ways and real-life scenarios. It was this that led her to the subject she thinks is most effective for explaining biology, chemistry and physics (and other STEM areas) to KS3 students, namely the prospect of colonising Mars.

Much of the initial groundwork for the lessons has been completed, including the lesson structure templates (figure 4), and Angela is now finessing the materials to match the Donaldson (2015) report recommendations and meet all the curriculum targets. She has planned Mars as the first theme for science education in Cardiff under the new curriculum and wants to develop a full set of themed resources.

"As a result of Donaldson, topics will no longer be taught in distinct packages and will not follow the more traditional approach i.e. Cells, Forces, the Periodic Table etc. will be no longer taught as topics on their own. The Biology, Chemistry and Physics content of KS3 will be covered within themes."
(Darke, 2018)

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(Darke, 2018)

Darke considers the idea of travelling to, and potentially colonising, Mars to be an inspirational and aspirational topic, with relevant ties to current science discussion. Having identified key areas for study and investigation (including the atmosphere, respiration, food chains and the carbon and nitrogen cycles), she is currently trialling resources based around these areas, to be finalised and rolled out in 2020.

The current plan is to design resources with a 'Mission to Mars' style, ideally enhancing the appeal for KS3 pupils, and making them more inclined to engage fully in science lessons.

A key point made by Darke is that the game should take no longer than 20 minutes to play, in order to fit smoothly into the average hour long lesson.

[5] Mrs Angela Darke is the Head of Science at Cardiff West Community High School, she has been teaching science in Wales for over 20 years.

2.4 Why Use Educational Games?

Much educational teaching and assessment over the last few decades has been largely based on the use of rote-memorisation, a method few people enjoy and that suffers from being slow and subject to rapid forgetting (Reyna, 1996). Many studies have shown that children's learning is greater when they become engaged in an activity and engage others in it as well (Azimita, 1988) (Wasik, 2008). One way to increase engagement is through educational games that enrich teaching strategies, by simulating the processes of decision making in an unconstrained setting (Henry, 1997).

For example, in the book 'Ender's Game' by Orson Scott Card, children are mostly taught through a curriculum of electronic and physical games, often working as teams or learning from and improving on what other students are doing (Card, 1985). Card himself was a games critic and considered many educational games to fall flat, as they use a simple drill-and-practice method that makes them no better than flashcards (Squire & Jenkins, 2003). He emphasises that people, not just children, need their decisions to be respected and should be allowed to explore, fail and then start again and considers many schools to be eliminating the joy of learning (Card, 2014).

Yet all of this should be done within a set of rules and restrictions, which is a concept board games bring into play, as this pushes on our creativity (Card, 2014). Game-based learning has recently gained traction with teachers as an active learning approach (Coil et al., 2017). Table-top[6] games can present complex systems as simplified models within the games play mechanics (Bochennek, 2007), which makes them an effective tool for transferring skills to players. Not only can they be effective, but games also include elements of competition and surprise, which can motivate students in a way standard lecture-style teaching does not (Gershen, 1974).

While both card and board games can be used to promote active learning and improve communication skills, via interacting with other players (Neame & Powers, 1981), they do not necessarily result in good learning simply by being a good game (Bochennek, 2007). As an analytical learning process (Gibbons & Hopkins, 1980), game play is experiential due to every turn or game repeating the learning stages (Bochennek, 2007).

Where educational games fail is in the development process. The mechanics, design and storytelling that make commercial games so appealing and compelling is often ignored in the educational context. This can result in products that try and combine entertainment and education but end up being as interesting as a bad lecture and lacking in informative content (Squire & Jenkins, 2003). Where pedagogical games have become popular is in the gamification of science, making it more accessible and interesting, increasing engagement in the subject material (Coil et al., 2017).

[6] Table-top games can refer to any games traditionally played on a table or flat surface, including board games, card games, dice games, miniatures (wargames) or tile laying games

2.5 Team Based Gaming

While researching educational games one important recurring aspect was whether the games are played alone; with a teacher, educator or parent, or as part of a group with peers. According to Squire (2003), when Card talks about educational games he presents an ideal of them not replacing textbooks but instead being like school corridors, where he believes children can experiment, interact, create and share (Squire & Jenkins, 2003).

By playing games in small groups children can be monitored and guided by a teacher, giving that teacher the chance to direct the gameplay towards the overall educational goal (Wasik, 2008). Studies have shown that, even beyond the game mechanics idea, learning can be enhanced through collaboration with peers (Azimita, 1988) (Howe et al., 2007). This may work particularly well in a games context, as games allow you to participate in social practices, and this social impact may be a factor in why and how people play board games (Squire & Jenkins, 2003).

Board games can also excite discussion, within the group while playing, when planning potential tactics and making suggestions for other players moves. Then after play, between groups by encouraging the comparison, and sharing, of their different experiences and how or why that may have succeeded or failed. Games give the teacher an opportunity to extend student learning both during and after play (Wasik, 2008).

2.6 Market Research

As education is fundamental in the life of every child in the UK, and globally, a large market place has developed around it, meaning that the concept of an educational game is not new. When it comes to the marketplace many educational games are quiz based, similar to a 'Trivial Pursuit' style, as these are simple to create and can easily simulate test conditions (Bochennek, 2007). To reach higher levels of communication and complexity games that involve roleplay, or the simulation of different scenarios should be used (Bochennek, 2007).

Using a Google Chrome extension ('Unicorn Smasher'), on the online shopping website Amazon, allows the production of tables that give an insight into the market place of both educational and space games to be created, see tables 2 and 3 respectively. They give an idea of average commercial cost to aim for and potential sales figures. While these tables can give a quantitative measurement of the market it is also important to understand what the public may be looking for or researching. 'Answer the Public' is a website that allows you to enter a search term and returns a list of the most common searches related to it. A list related to the search term 'educational games' can be seen in appendix figure 2.4.

Product	Brand	Sellers	Variations	Price	Category	Rank	Est. Sales	Est. Revenue	Reviews	Rating	FBA
Skillmatics Educational Game	Skillmatics	1	1	-	Toys & Game	3,980	6,631	$0	4	5	-
Skillmatics Educational Game	Skillmatics	1	1	-	Toys & Game	7,633	6,162	$0	4	5	-
		1	1	-			-	-			
Educational Insights Kanoodle	Educational Insights	1	1	$6.99			-	-	584	4.6	AMZ
Educational Insights Pancake	Educational Insights	1	1	$15.75	Toys & Game	5,763	6,379	$100,469	262	4.6	AMZ
Rory's Story Cubes	Gamewright	1	1	$7.97	Toys & Game	2,740	6,850	$54,595	1,323	4.5	AMZ
Educational Insights The Snea	Educational Insights	1	1	$13.11	Toys & Game	222	7,710	$101,078	1,377	4.7	AMZ
BRAIN GAMES KIDS - Warning	Buffalo Games	1	1	$15.39	Toys & Game	10,348	5,898	$90,770	38	4.4	AMZ
Spot It!	Asmodee	1	1	$11.69	Toys & Game	306	7,642	$89,335	6,732	4.8	AMZ
The Learning Journey Match I	The Learning Journey	7	1	$12.99	Toys & Game	1,527	7,134	$92,671	857	4.7	AMZ
Skillmatics Educational Game	Skillmatics	1	1	-	Toys & Game	21,661	5,115	$0			-
Skillmatics Educational Game	Skillmatics	1	1	-	Toys & Game	202,206	957	$0			-
DK Games: Silly Sentences		1	1	$8.99	Books	2,344	22	$198	141	4.3	AMZ
HedBanz Game - Edition may	Spin Master Games	1	1	$11.92	Toys & Game	329	7,626	$90,902	1,672	4.6	AMZ
Animal Math Kindergarten M	Eggroll Games	1	1	-			-	-	72	4	-
Bananagrams	Bananagrams	55	1	$13.60	Toys & Game	504	7,518	$102,245	2,276	4.7	FBA
The Learning Journey Match I	The Learning Journey	1	1	$12.99	Toys & Game	3,662	6,682	$86,799	264	4.6	AMZ
Educational Insights The Snea	Educational Insights	1	1	$13.11	Toys & Game	11,974	5,761	$75,527	700	4.7	AMZ
My Feelings Game. Fun educa	Sensational Learners	1	1	$29.95	Toys & Game	26,627	4,855	$145,407	47	3.9	FBA
Educational Insights Robot Fa	Educational Insights	1	1	$19.23	Toys & Game	11,561	5,795	$111,438	126	4.4	AMZ
Learning Resources Money Ba	Learning Resources	1	1	$15.89	Toys & Game	9,755	5,952	$94,577	304	4.6	AMZ
Mag-Genius Award Winning I	Mag-Genius	1	1	$24.98	Toys & Game	9,395	5,985	$149,505	140	4.7	FBA
Skillmatics Educational Game	Skillmatics	1	1	-	Toys & Game	35,158	4,470	$0			-
Average:		**4**	**1**	**$10.20**	**Toys & Games**	**15,987**	**5,006**	**$60,240**	**736**	**3.8**	

Table 2 Amazon data on a search for 'educational+games' (Unicorn Smasher, 2018)

Product	Brand	Sellers	Variations	Price	Category	Rank	Est. Sales	Est. Revenue	Reviews	Rating	FBA
Qurious Space	Qurious	1	1	$16.90	Toys & Games	14,767	5,549	$93,778	82	4.4	FBA
Butts in Space:	Butts in Space	1	1	$25.00	Toys & Games	35,829	4,443	$111,075	1	4	FBA
		1	1	-			-	-			
Elite Space Troo	Top Shooter Games	1	1	-			-	-	5	3.5	-
Space City: buil	Sphere Game Studios	1	1	-			-	-	68	4	-
Adventure Esca	Haiku Games	1	1	-			-	-	249	4.1	-
Jump Drive	No Six Five	1	1	-			-	-	4	5	-
Qurious Space	Qurious	1	1	$16.90	Toys & Games	14,767	5,549	$93,778	82	4.4	FBA
Earth Editor	DAN-BALL	1	1	-			-	-	47	4.3	-
My Colony	Ape Apps	1	1	-			-	-	75	4.2	-
Skillmatics Edu	Skillmatics	1	1	-	Toys & Games	32,574	4,580	$0	1	5	-
jackinthebox Sp	jackinthebox	1	1	$25.99	Toys & Games	4,989	6,481	$168,441	4	5	FBA
Interstellar Pilo	pixelfactor	1	1	-			-	-	77	3.8	-
Space fighter	RBGames	1	1	-			-	-			-
Space Jet: War	Extreme Developers	1	1	-			-	-	21	3.6	-
Planet Speeder	TurboNuke Ltd	1	1	-			-	-	11	3.4	-
Planet Smash -	Pocket Labs	1	1	-			-	-	378	4.6	-
Mines of Mars	Crescent Moon Games	1	1	-			-	-	1,455	4.4	-
Tiny Epic Galax	Gamelyn Games	18	1	$24.98	Toys & Games	16,303	5,443	$135,966	163	4.7	FBA
Star Trek Timel	Tilting Point	1	1	-			-	-	104	3.6	-
Galax Defender	Luis Medel	1	1	-			-	-	127	3.6	-
Laser Tag-Laser	Toyard	1	1	$29.99	Toys & Games	246,851	411	$12,326	4	3.4	FBA
Schylling Classi	Schylling	1	1	$17.95	Toys & Games	138,290	1,906	$34,213			FBA
Average		**2**	**1**	**$6.86**		**21,929**	**1,494**	**$28,242**	**129**	**3.6**	

Table 3 Amazon data on a search for 'space+games' (Unicorn Smasher, 2018)

Through discussions with gamers and staff from Firestorm Games Cardiff[7], a list of relevant games, based around science, space and Mars, was constructed. These themes were explored further based on the interview with Angela Darke and her Mars-themed lesson planes. Analysis of the games, their design and mechanics, may give some clue as to the current table-top games market.

Figure 5 Destination Mars board and player pieces (GeekBuddy Analysis, 2008)

Figure 6 Destination Mars game box, board and parts (GeekBuddy Analysis, 2008)

The first game to consider is 'Destination Mars' (1999) a two-player, 20 minute game for ages 8+ (GeekBuddy Analysis, 2008), shown in figures 5 and 6. The game employs a 'space-race' system, where players compete to be the first to reach Mars by matching cards (figure 7) for points (GeekBuddy Analysis, 2008). Destination Mars shows that a simple game can be played within the recommended 20 minutes, while still tying in some teaching elements on the cards and being for an appropriate, if slightly younger, audience.

Figure 7 Destination Mars game cards (GeekBuddy Analysis, 2008)

'Dig Mars' (2013) (figure 8), is also designed for the 8+ market, where players are aiming to obtain a set number of 'fortune points' by moving around Mars' surface and digging for minerals and ores (GeekBuddy Analysis, 2013). It takes closer to 30 minutes to play but adds in a story aspect through "captain logs" that create more context for play (GeekBuddy Analysis, 2013).

Game review sites review the level of complexity of game play, giving them a 'weight' rating. Both 'Destination Mars' and 'Dig Mars' have relatively low 'weight' ratings, between 1-2 out of 5 (GeekBuddy Analysis, 2008) (GeekBuddy Analysis, 2013). These games show that relatively complex scenarios, such as reaching and inhabiting Mars, can be implemented in a simple game that is easy to pick-up and play. This suggests that this can be recreated in the context of teaching students about science, and specifically space related science topics.

Figure 8 Dig Mars game play layout (GeekBuddy Analysis, 2013)

It is still important to consider board games with more complex game mechanics and that might take a longer time to complete, as they may involve aspects that are scalable for the purpose of this project. Two other games to look at are the middle ground 'Terraforming Mars' (2016), with a complexity rating of 3.24, for ages 12+ (GeekBuddy Analysis, 2016), and an upcoming title 'On Mars' (figures 10 & 11) due out in 2019 with a complexity rating of 5 out of 5 for ages 14+ (GeekBuddy Analysis, 2018).

Figure 10 Box concept graphics for the On Mars board game (GeekBuddy Analysis, 2018)

Figure 9 A group playing the Terraforming Mars game (GeekBuddy Analysis, 2016)

Figure 11 Full layout of On Mars board game showing all parts, pieces and cards (GeekBuddy Analysis, 2018)

[7] Firestorm games is an independent table-top games retailer with three large stores, in Cardiff, Newport and Swansea. In Cardiff the store has a venue with a bar and 70 gaming boards where they host events such as national and regional gaming competitions.

2.7 Analysis of Educational Games

Educational games have previously been developed for a variety of reasons and subjects. This section reviews findings from previous STEM based pedagogical games, considering where they have been used and the success of their implementation, amongst other factors.

Ramani et al. (2012) found that when playing a number-based board game in the classroom, the number line estimation accuracy rose from 65% to 70% and the magnitude comparison rose from 65% to 73% in KS1 children. They also found that when playing the game children remained focused and attentive (engaged) throughout multiple iterations of play, declining only 3% between the first and last games, from 95% to 92% (Ramani et al., 2012). Their findings suggest that it was not just the novel experience of playing a board game in class that got the children engaged and learning, but the fact that the experience was enjoyable and they could learn from each other (Ramani et al., 2012).

'Gut Check' is an educational biology game initially developed for high school students and undergraduates that could be downloaded, printed off and played for free at home or school (Coil et al., 2017). The game ended up being popular with children as young as 6 and its success led the creators to develop a commercial version that could be bought and sold commercially (Coil et al., 2017). It took one year for the team, all of whom had no previous experience, to design the print-at-home version, play-testing it with both gamers and biologists. The card development can be seen in figure 12. While there has been no official research into how well this game teaches players, it has been used in a number of classrooms and is popular with students (Coil et al., 2017).

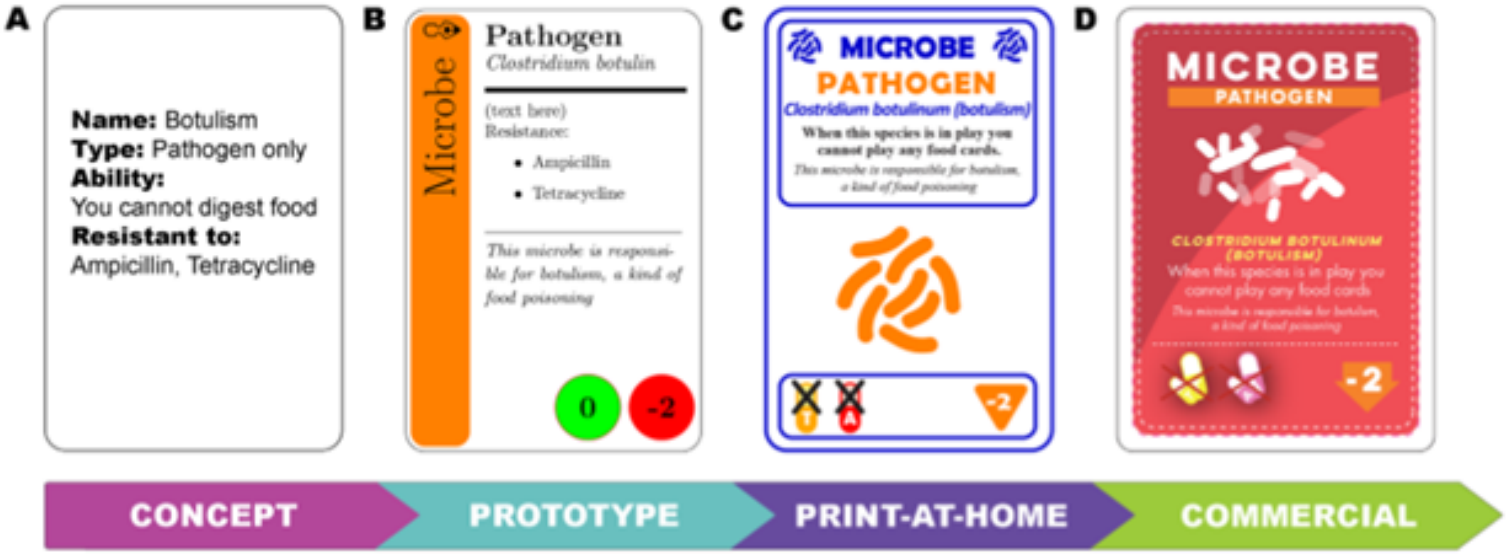


Figure 12 Gut Check cards from initial concept to final edition (Coil et al., 2017)

Eckert (2004) researched their educational games about B-/T-lymphocyte self-tolerance, which is meant to aid understanding of immunology. With different cards being played to represent different elements of the immune system, 95% of 120 students demonstrated an increased knowledge after playing the game (Eckert, 2004). Both the B-lymphocyte and T-lymphocyte versions of the game include stages of planning, with play being tactical and the cards graphic, which led to significant improvements in student grades (Eckert, 2004).

'A Trading Game about Host Defence' is another game used to teach immunology to adolescents (Steimen & Blastos, 2002). Players need to both defend their own organs using medications, vaccinations or surgery, while also attacking the oppositions with a variety of viral, bacterial, fungal and parasitic infections. A review by Steimen and Blastos (2002) showed that playing the game caused an increase in test scores for 8th graders, those aged 13-14 (from 39% to 58%), 10th graders (47%-59%) and in medical students (80%-88%).

Pedagogical games were again tested when Trevino et al. (2016) split 42 optometry students into two groups to complete their 'Optometry challenge', ensuring that the two halves had no difference in pre-test scores. While one half were taught through 12-hours of interactive lectures the other half played an educational game for 12 hours (Trevino et al., 2016). The results of this study showed no significant difference in post-test scores, demonstrating that game play was as effective a tool for teaching as an interactive lecture experience (Trevino et al., 2016). The participants also completed a survey after the 'Optometry challenge', showing slightly higher levels of enjoyment in the game and equal motivation to learn (figure 13).

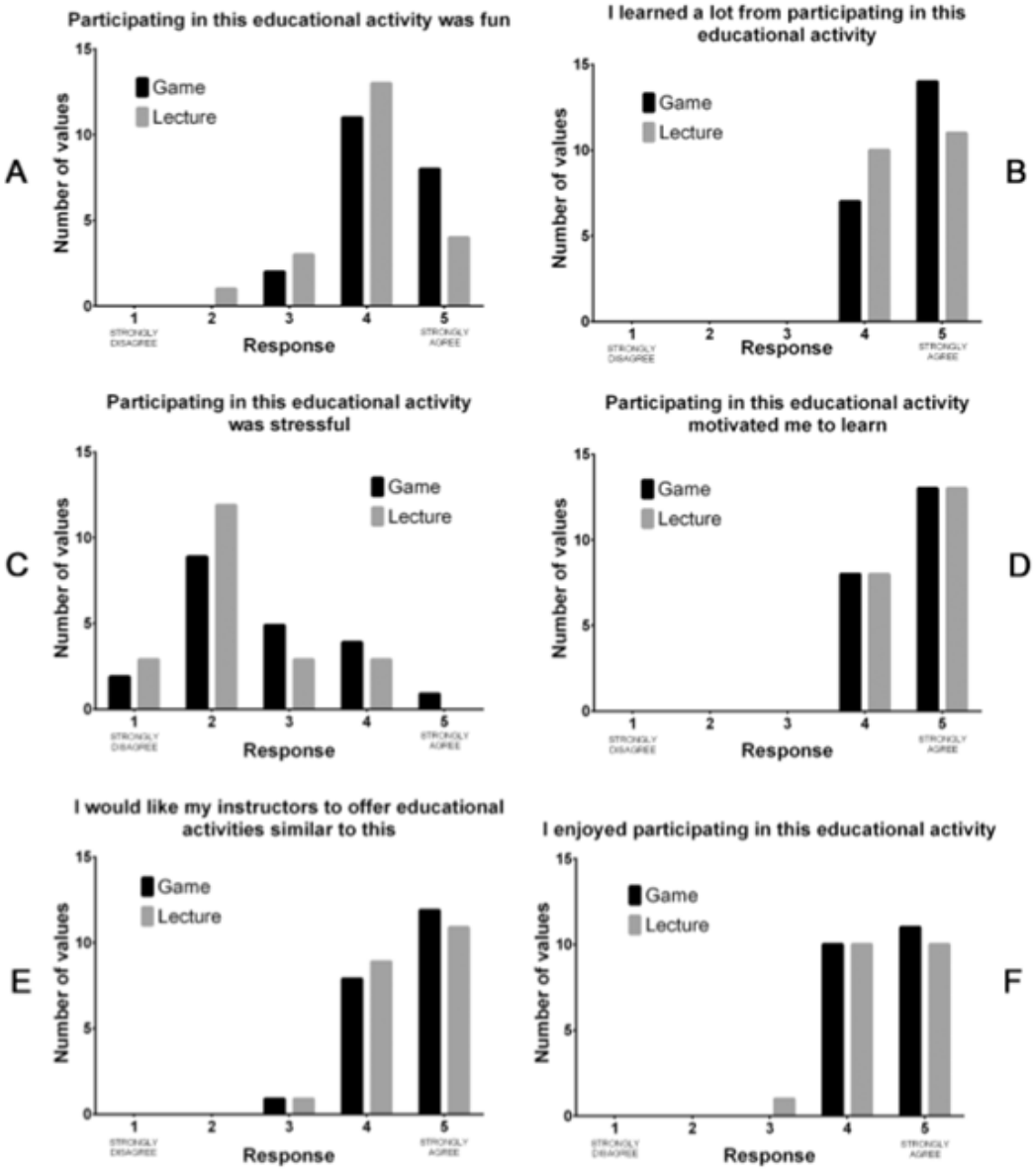
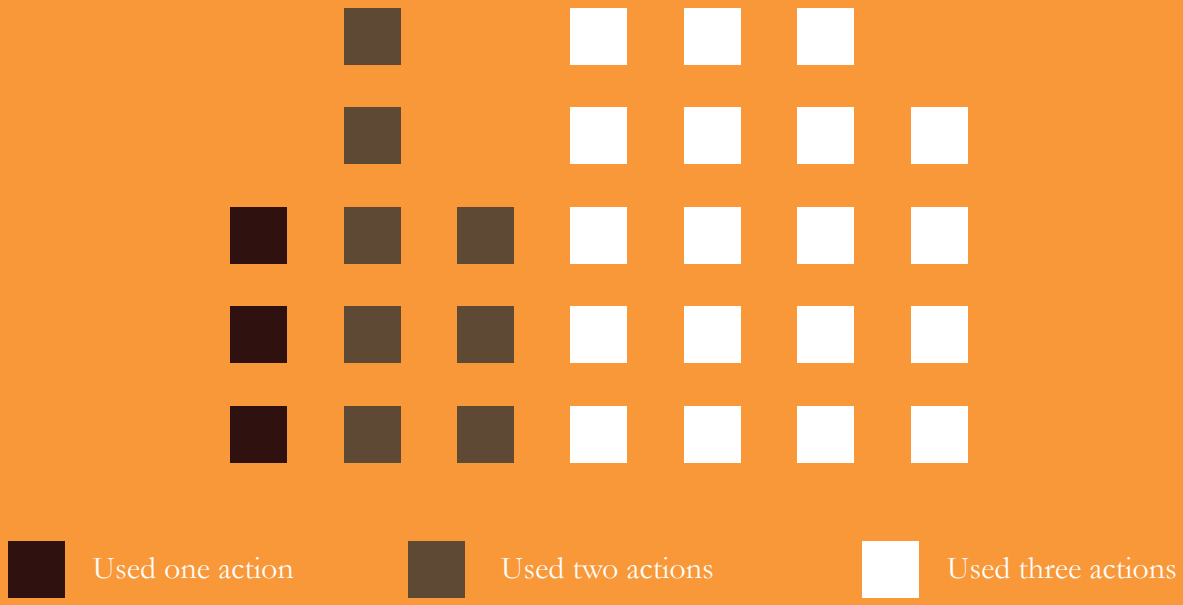


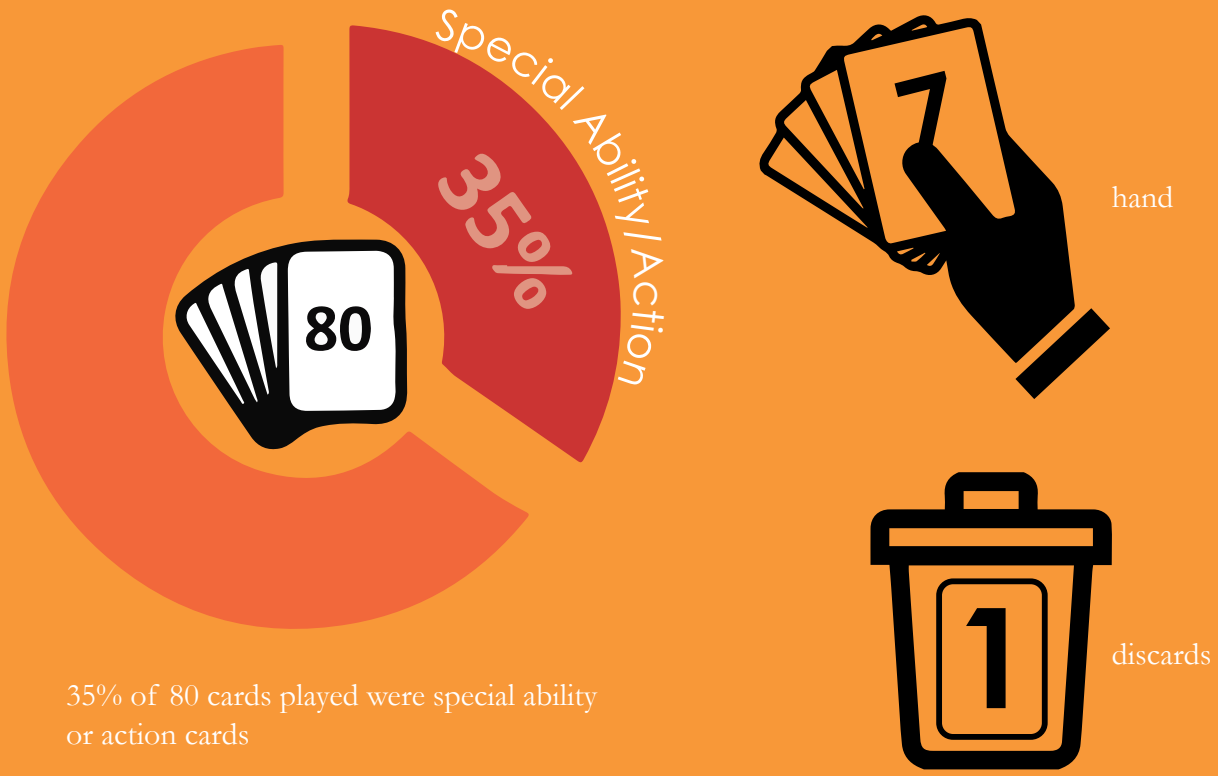
Figure 13 Responses to post-learning opinion survey (Trevino et al., 2016)

2.8 Competitor Analysis

Understanding the mechanics of games designed for children and playable in a 20-minute, or less, time period.

Monopoly Deal[8]:





35% of 80 cards played were special ability or action cards

Figure 14 Monopoly Deal game play analysis infographics

[8] 'Monopoly Deal' is a card game derived from the board-game Monopoly introduced in 2008, produced and sold by Cartamundi under a license from Hasbro. For ages 8+, players 2+, game time ~20 minutes. The aim is to get 3 sets of monopolies, action cards can force other players to pay you rent, trade properties etc.

Escape the Curse of the Temple[9]:

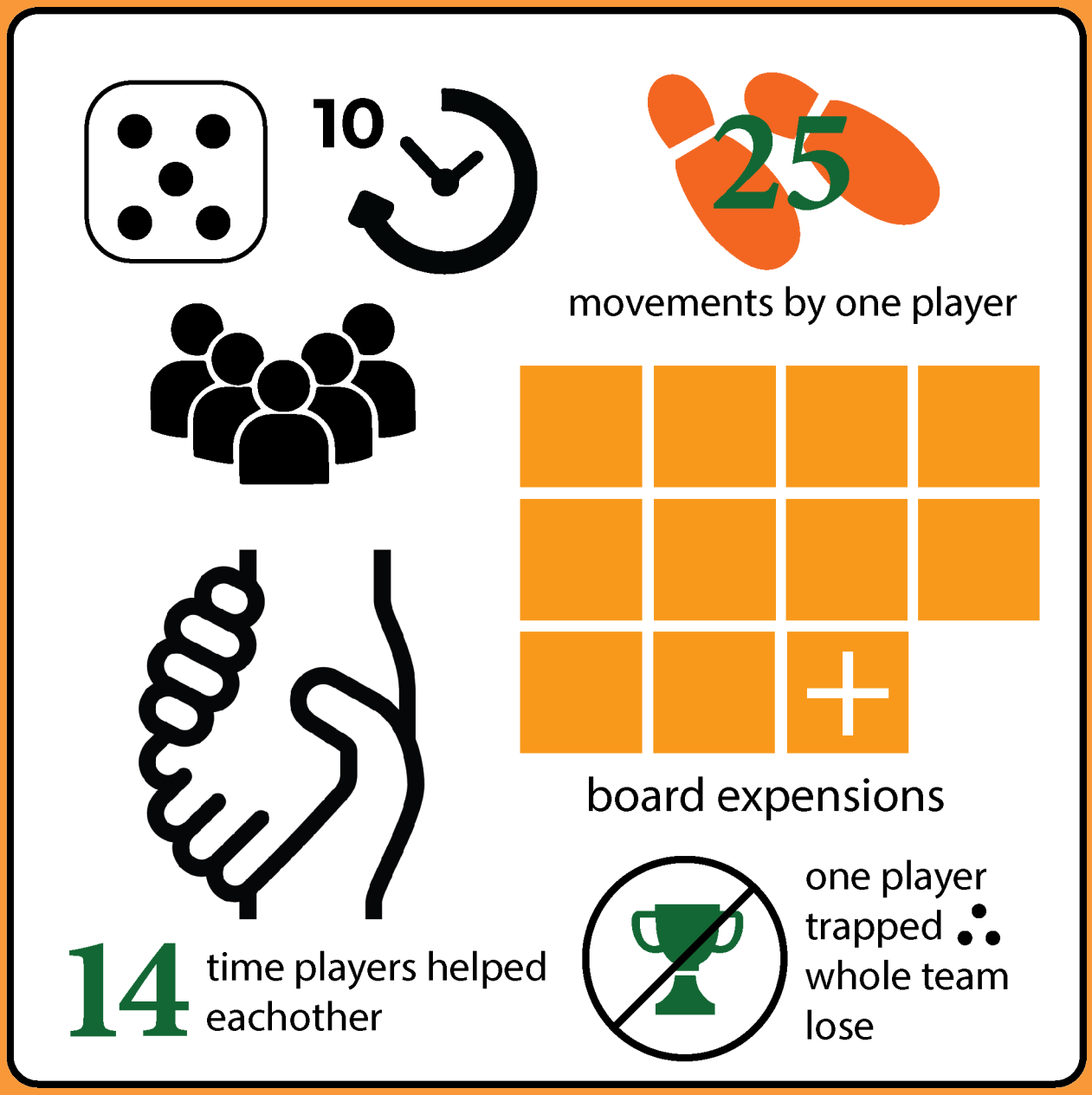


Figure 15 Escape the Hidden Temple Game Play Analysis

[9] 'Escape the Curse of the Temple', where players try and help each other navigate out of a collapsing temple, within a ten-minute time limit. Each player has five dice, with symbols that allow for movement and unlocking tiles to explore. Players can also get cursed or locked out of rolling their dice, and other players can then help them using their own dice rolls. The game works in real time so players must communicate well to complete their task within the ten minutes while also listening out for when their team mates may need help.

2.9 The Target Market

Y7 is the year in which students transition from primary to secondary schools in the UK, meaning pupils find themselves in a new environment, with new people, which may impact on their confidence as they try and find where they fit in. Gamification of content can encourage communication with peers and allow students to feel like they belong as part of the group (Pandey, 2015). It has the potential to create a better learning experience and environment, helping users to feel both more comfortable and confident.

As the game will be focused on KS3 science, the age range of the target market is 11-14 years old. Whilst focus will be on students in the classroom, there is no reason that a fun and challenging game cannot be developed that will both excite interest outside of the age range and encourage play beyond the classroom setting.

It is during the 'tween' years (11-13) that children begin to develop cognitively, into a more adult-style of thinking (Anthony, 2013). It is logical for them all to develop this at slightly different periods, in the same manner all children learn to walk at slightly different ages, therefore resulting in mixed ability classes. Within the school system the methods of teaching mixed ability classes need to be adapted, shifting the approach to education, and opening new opportunities and goals (Kelly, 1974).

Eleven- and twelve-year olds begin to think about abstract concepts and concrete operations, allowing them to demonstrate logical thinking skills, be more strategic and use methodical approaches (Anthony, 2013). It is during this time that children begin to formulate their values and egocentrism emerges, often in the form of self-consciousness (Anthony, 2013). The expected social, emotional and maths skills of the age range are summarised in figures 16 and 17.

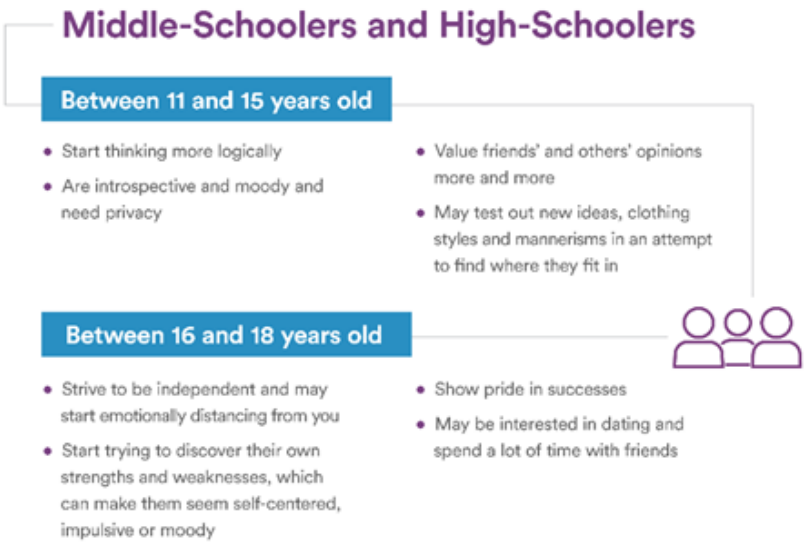


Figure 16 Social and Emotional Skills: What to Expect at Different Ages (Morin, 2014a)

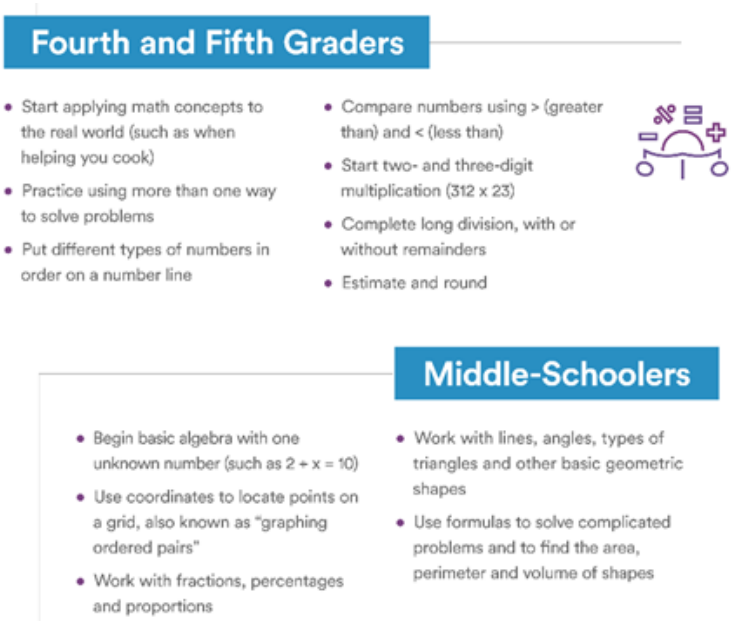


Figure 17 Math Skills: What to Expect at Different Ages[10] (Morin, 2014b)

		How much does it mean to you to do well at school?	How happy are you with your school work?	I like most of my teachers	Teacher are always getting at me
		% Positive	*% Positive*	*% Agree*	*% Disagree*
Year 7	**Boys**	95	77	83	83
	Girls	98	86	89	94
Year 8	**Boys**	96	79	69	80
	Girls	97	85	76	88
Year 9	**Boys**	96	80	67	75
	Girls	97	85	71	82

Table 4 Young Peoples Attitudes to School by Age and Gender (Croll, 2003)

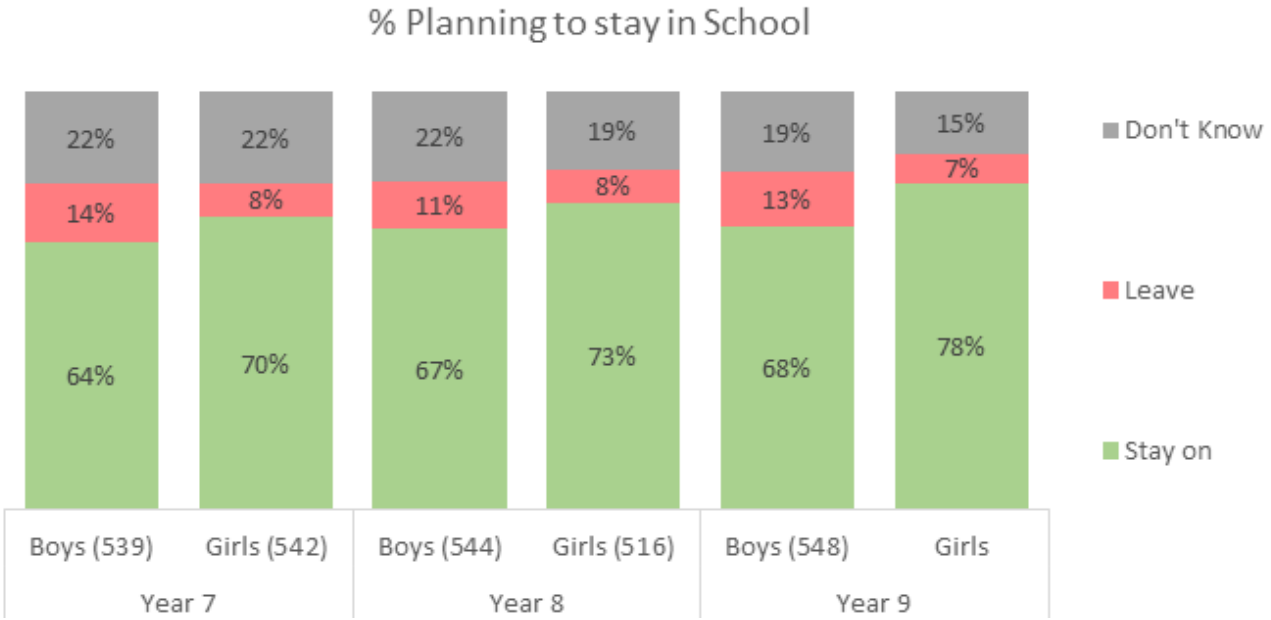


Figure 18 KS3 students plans post compulsory education (Croll, 2003)

The Department of Health (2014) consider the wellbeing of children to be tied to their experience of school[11], making it important to have a positive class environment.

An investigation into young people's attitudes to school was carried out in 2003 - the main findings are summarised in Table 4. While this might give some insight into attitudes in the target age range, it is important to remember this was a different generation of children, mostly raised without the abundance of and reliance on technology we see today. However, it can be seen that overall the majority of KS3 children's attitudes to school are positive, with most planning on carrying on in education in the future (Croll, 2003).

[10] Fourth and fifth grade are equivalent to years 5 and 6, making them part of KS2

[11] Experiences at school other than bullying are important to young people's wellbeing. 7% of 10 to 15-year-olds report that they do not feel safe at school, but these young people are far more likely to report low levels of wellbeing (35% vs. 11% of the rest of the sample). In contrast, 11 to 15-year-olds who experience a strong sense of 'school belonging' are more likely to have high levels of wellbeing than those who experience weak, or medium feelings of school belonging.

2.10 Board Game Design

There are many variations when it comes to table-top and board games, but the main types can be described as:

- Roll and move games
- Quiz games
- Worker placement games
- Cooperative games
- Deck building games
- Area control games
- Secret Identity games
- Legacy games (affected by previous play decisions)
- Puzzle games
- Combat games

(Strategist, 2018)

As every board game is different, in terms of their purpose, design and mechanics, there is no set method or guidelines on how to design them (Silverman, 2013). There is however a basic order that should be considered. First establishing the actual content, then simplifying that before organising the interactions that will occur during play (Silverman, 2013). Once this has been done a set of rules and instructions can be developed, which leads to the creation of a prototype that can be play tested continuously. The game can then be adapted and balanced based on feedback (Silverman, 2013).

Silverman (2013) sets out a list of questions they recommend you ask yourself before the process of designing a board game:

"How many players will there be?
How long should the game be?
What choices will the player make, and when will they make them?
How will the player make these choices?
How will one player's choice impact the other players?
How will the players interact with each other?
Are there any choices that can be made by one player, but not by the others?
How does the game progress?
Is it strictly turn-based, or is it in rounds with phases?
What actions will the player(s) be able to take?
How will the outcome of an action be determined?
What is the player's goal?
How can the player(s) win?"
(Silverman, 2013)

Board games are considered a toy and must be designed and tested to fall within the BSI EN-71 standards for toy safety, if the game is intended to be used by those aged 14 and under (Sears, 2017) (BSI Group, 2016).

The key relevant standards are that the product must contain no parts that can stab, trap, mangle or choke; and ensuring children are not at risk from elements such as lead, cadmium and mercury (BSI Group, 2014).

2.11 Considering Alternative Games Styles

It is important to consider that board, and table-top, games are not the only option. While they may be the easiest to implement in a large portion of schools and classrooms there are a variety of other games that could be used. These include the use of physical activity, that may require an outside or at least a large open environment, and video games, including augmented and virtual reality, that require the use of up-to-date technology.

Physical games can include sports or any other game that uses motion and movement as a key mechanic in play. They normally focus on a person's body, rather than their mind (Collins Dictionary, 2018) which would be a distraction from the educational aims of this project.

Video games allow users to electronically control play and images on a screen (Merriam Webster, 2018), using a specialised device, computer or mobile phone and can also include arcade-style games that are controlled with micro-controllers (dictionary.com, 2012).

However, both these types of games rely heavily on schools having the appropriate resources, and undertaking risk assessments, therefore a table-top game has been selected as the most suitable format for this project.

3.0 DEVELOPMENT PROCCESS

3.1 Design Brief

The aim of this project is to create the first in a series of three boardgames, designed to teach STEM subjects to KS3 students, under the name 'Mission to Mars'. The first game will be aimed at Y7 (ages 11-12) and will have a focus on the aspects required to land a manned rocket on Mars, including take-off, navigation and landing. The Y8 game will focus on base building and survival, while the Y9 game will revolve around exploring the planet.

As the boardgame will be part of a series, branding and design guidelines will need to be established. A colour scheme will need to be developed, a logo designed, typefaces selected, and the overall design feel established.

The game must be co-operative and simple to pick up and play in 20 to 30 minutes. Along with teaching KS3 science it must encourage the development of wider skills, as outlined by Donaldson (2015). It must be suitable for teams of 3-6 within a mixed ability classroom and not require constant teacher supervision.

The final product will be a game board, along with any required game pieces or cards, with a set of instructions. The final product will encourage interest and engagement in KS3 science, while developing children's knowledge in areas such as problem solving, teamwork, communication and critical thinking. At the same time the game must be enjoyable and fun to play, with balanced play mechanics that make it achievable but not exceedingly easy to win.

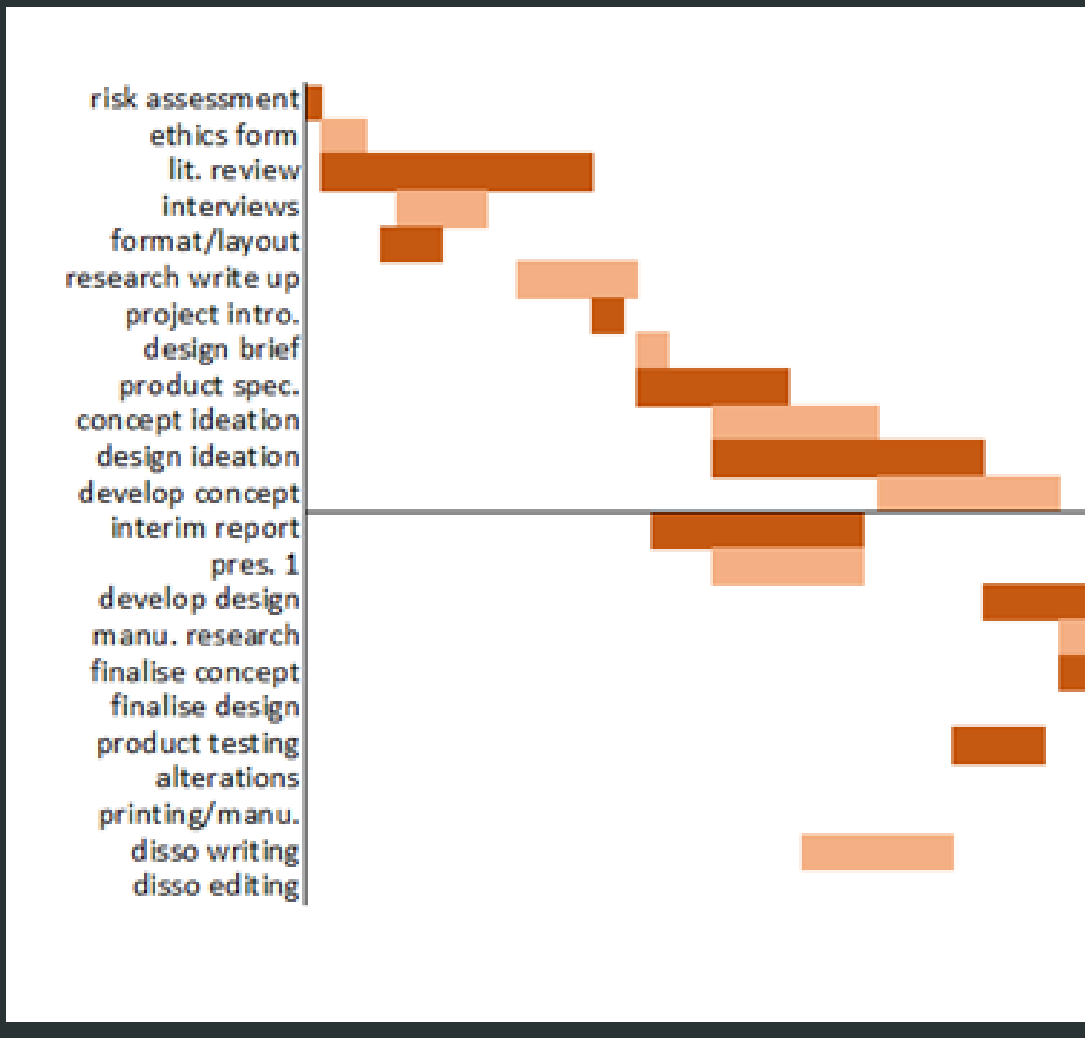
3.2 The Project Plan

The project must be completed by a set date. To ensure everything is completed to deadline a schedule has been developed. This includes a timetable depicting how many hours are required for each task (table 5), a critical pathway which outlines the order in which tasks must be completed (table 6) and a timeline that shows when tasks should be started and completed by (table 7).

To ensure work is progressing at an appropriate rate, regular meetings will be held with the project supervisor. Fourteen sets of minutes from these meetings are in appendix figures 3.1 to 3.14.

TASK	HOURS																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Risk Assessment																									
Ethics Form																									
Background Research - lit reviews																									
Background Research - interviews																									
Format Dissertation Layout																									
Background Research - write up																									
Draft Introducation																									
Define Product Brief																									
Draft Product Specification																									
Initial Concept Ideation																									
Initial Design Ideation																									
Concept Development																									
Write Interim Report																									
Write Viva Presentation																									
Design Development																									
Manufacturer/Printer Research																									
Finalise Concept																									
Finalise Design																									
Product Testing																									
Product Alterations																									
Product Printing/Manufacture																									
Dissertation Write-up																									
Dissertation Editing																									
TOTAL TIME =	**287 hours**																								
Lectures/Supervisor meetings ≈	**100 hours**																								

Table 5 Project timetable of tasks and hours to complete



Task	2018												2019															
	October				November				December				January				February				March				April				May			
risk assessment																												
ethics form																												
lit. review																												
interviews																												
format/layout																												
research write up																												
project intro.																												
design brief																												
product spec.																												
concept ideation																												
design ideation																												
develop concept																												
interim report																												
pres. 1																												
develop design																												
manu. research																												
finalise concept																												
finalise design																												
product testing																												
alterations																												
printing/manu.																												
disso writing																												
disso editing																												

Table 7 Project timeline

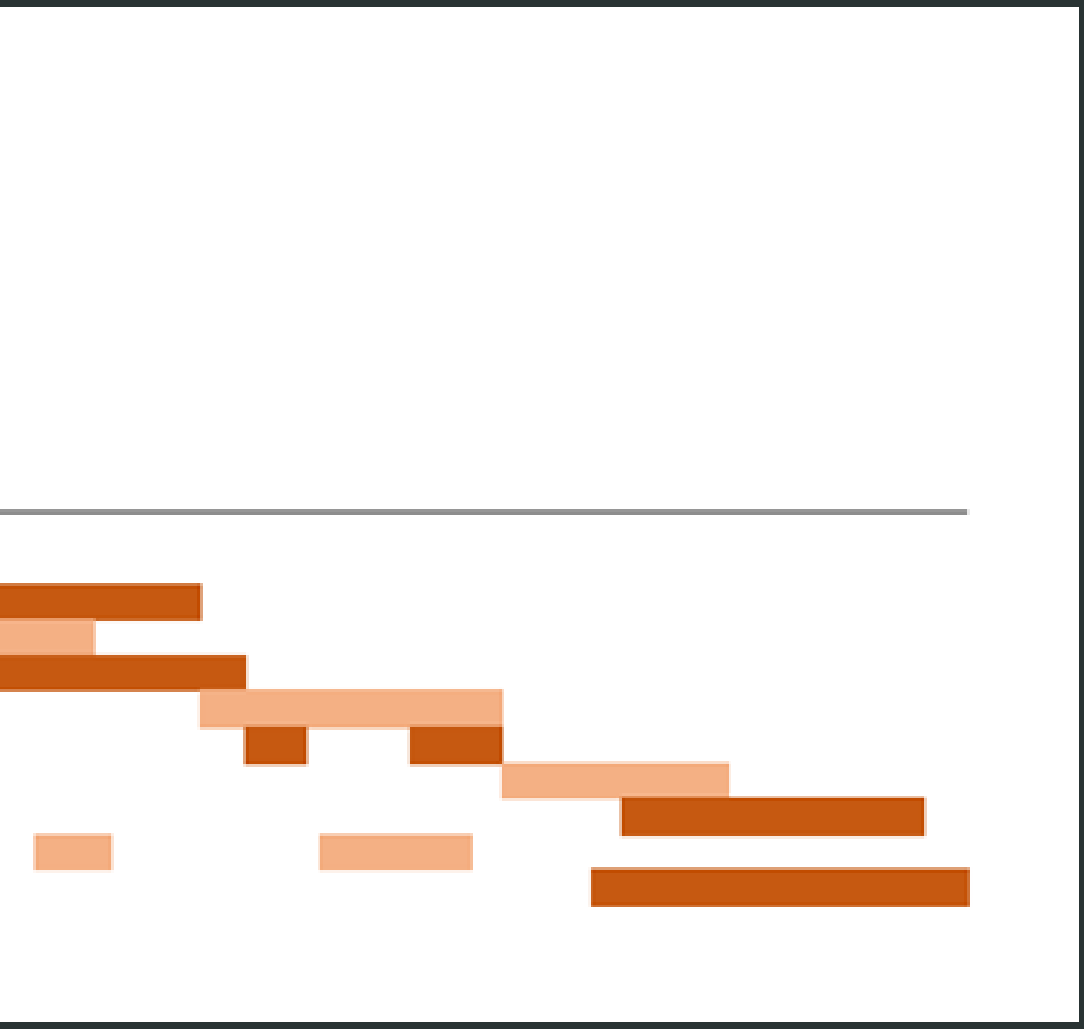


Table 6 Project Critical pathway, showing order of work completion

3.3 Product Specification

Before design work could be undertaken a design specification needed to be generated. Below is a list of project requirements that must be met:

PROJECT DELIVERABLES:

- A complete playable game including a game board and all game pieces including cards, tiles and dice
- Instructions on how to play the game
- Qualitative data from product testing
- Final design renders and images
- Final written report and presentation explaining the entire duration of the project and evaluating the final design
- Two A2 presentation boards

FUNCTIONAL PERFORMANCE:

- Game completion must be achievable, but should provide a challenge
- Game must be cooperative, for three to six players
- Game must include content from KS3 science curriculum
- Game must be based around Mars and Space
- Game must encourage the use of wider skills, such as communication, leadership, teamwork and problem solving
- The game must take no more than 30 minutes to play
- All instructions, cards and tiles must be easy to read and understand
- The product should work in tandem with other class activities and resources

TARGET DEMOGRAPHIC/MARKET:

- Game must be suitable for 11-14 year olds
- The game must be designed to fit within a school/ classroom environment
- Users should feel they are rewarded in some way for completing the game
- The game must be simple to pick up and play, without the need for teacher/adult supervision/ monitoring
- The game should encourage interest and engagement in the sciences and STEM subjects to the target market users

AESTHETICS:

- The game must be designed to the guidelines laid out for the 'Mission to Mars' branding, including colours and typeface
- The game must appeal to the 11-14 age range
- The aesthetics must be themed around Mars and Space

TIME SCALE:

- All deliverables will be finished by the 01/05/19 deadline

MAINTENANCE:

- The game must still be playable and beatable if any one component goes missing
- The game will not include any fragile pieces that can easily break
- All surfaces must be able to be easily cleaned
- The product life-span should be a minimum of 3 years, to cover the set years in Key Stage 3 (years 7, 8 and 9)
- Game components should be accessible online for ease of replacement via purchase
- Component files should be downloadable to allow for users to replace lost or broken components free of charge (including 3D printer files and card templates)
- Missions, cards and space agency facts will be regularly reviewed and updated versions made available online

HEALTH AND SAFETY:

- The product must meet BSI EN-71 standards for toy safety
- All primary research and testing must be approved by Brunel Ethics committee
- All workshop manufacturing of prototypes must be covered by Brunel workshops risk assessment
- All surfaces and edges must be smooth and not have any splinters, along with no sharp edges and corners

MATERIALS AND MANUFACTURE:

- Game pieces must not be made from any toxic materials
- The game pieces need to be durable enough to undergo continuous reuse
- All manufacturing processes should be approved by technician health and safety risk assessment
- 3D components should be easy to create using 3D printing technology

4.0 BRAND DEVELOPMENT

'Mission to Mars' (M2M) is a brand being developed following the proposed curriculum changes in Wales. Funded by a wider Welsh Government science education grant ('Trio Sci Cymru' – a joint programme between the universities of Cardiff, Swansea, Aberystwyth and Bangor – M2M falls within the Cardiff University "Universelab" programme, covering KS3 in particular). M2M will focus on developing resources for students in classrooms across Wales. As a new brand which hopes to enter pioneer schools in the 2019/2020 academic year for trialling, M2M needed to develop a selection of brand guidelines. The 'Mission to Mars' game is the first large-scale project to be developed for M2M and therefore will be developed alongside the design style of the brand.

A branding outline can be seen in appendix 4.1, followed by M2M branding research (4.2) and colour scheme (4.3). Finally, the M2M logo and brand values are available (appendix sections 4.4 and 4.5 respectively).

5.0 MATERIALS & MANUFACTURING

5.1 Materials Research

Game components can come in several materials depending on their purpose. Many games use wooden, metal or plastic figures to represent players and paper, cardboard or chipboard tiles. Plastic elements of board games are usually made from polystyrene, a widely used polymer (Spiele Material, 2015).

Playing cards can also come in the form of three different materials, plastic, vinyl or paper. Plastic is the most durable, with paper being the cheapest option but also the most likely to break, having to be frequently replaced (Stemple, 2016).

Most game boards are made from chipboard or cardboard of approximately 2mm thickness, with either one fold or two (Boardgames Maker, 2018). The finish of the board can vary, but for durability the best options are to either laminate (with gloss or matte finishing) or litho wrap (Boardgames Maker, 2018).

An alternative to game boards are game mats that can either be made from a felt material or non-slip rubber, which can make it easier to pick up cards or tiles from a surface and also prevent slipping (Tabletop Companion, 2018). The final option is to create a table top game that does not require the use of a 'board' and instead relies on players laying cards or tiles out on a flat surface.

5.2 Material Choice

The game cards will be made from layered paper, 63 x 88 mm in size, like many playing cards. This makes them an appropriate size for children's hands, and they are durable whilst still being affordable.

The mission tiles will be made from cardboard, with a coating for protection, making them durable and long lasting.

Other components, including player pieces and Mars sections, will be made from polylactic acid (PLA), a biodegradable plastic that can be 3D printed.

5.3 Manufacturing and Printing

All game parts that need to be manufactured, (e.g. the player pieces and central Mars building section), will be made through additive manufacturing. Not only does this prevent waste material during the manufacturing process, it also allows for all parts to be easily replaceable, using a 3D printer. Many schools now have 3D printing technology, therefore this is a way of extending the life-span of the game without having to spend extra money.

There are many online options for game card printing, for this project the company snapajacks[12] has been chosen. The game board and prototype mission tiles were purchased from boardgamemakers.com.

[12] www.snapajack.com is a Nottinghamshire based printing service, with a focus on fast printing and delivery

5.4 Environmental Impact

By using additive manufacturing, (i.e. material being added in layers, rather than cut away) for all plastic game components, waste material is avoided. This also means the game will not become unplayable through loss of parts as they can easily be replaced using a local 3D printer, optimising the life-span of the game.

In general, additive manufacturing is more sustainable than traditional manufacturing processes. Nevertheless, there is high electricity use in 3D printing, which needs to be considered if this process is used for mass manufacturing the game. While the full environmental impact of 3D printing is not yet fully understood, there is a clear positive in its opportunities for local production.

The choice to make components via 3D printing also defines the material being used, i.e. that used by commercial 3D printers PLA, which is biodegradable. Although biodegradable, it undergoes this process slowly, meaning whilst it is preferable to other plastic options, it is not a perfect solution.

The use of paper cards in the player deck may be a less durable option, in terms of tears and water damage, but almost all paper cards are recyclable. Considering the context of use and the likelihood for cards to go missing and needing to be replaced, or potential for facts to change or be updated, paper cards are a more practical option, being greener than plastic or vinyl cards and again having the option to be locally produced if needed.

6.0 GAME DESIGN

6.1 Game Concept Research

To understand board games and how people interact with them in more depth, two meetings were held with Andrew Walpole (Firestorm Games, Cardiff) and Dr. Mat Allen (scientist and board game hobbyist). Full notes from these meeting are in appendix figures 6.1 to 6.10. The main findings include the desire for games to tell a story, which can fully engage the player. People also like to have some *individualisation*, so allowing players to select their own character traits (which differentiates them from their team mates) should be considered. Other findings included the comments that *good games often involve making smart decisions, planning and a little bit of luck*.

Initial thoughts leaned towards players creating an appropriate/safe landing site on Mars by terraforming the surface. Upon further consideration it was decided that this would be a more suitable concept for a Y8 game. Discussion then moved on to the board game 'Celestia'[13], which involves players making their way up a map. Players simultaneously have to work together and are also competing, creating interesting play dynamics.

As this game wants to encourage cooperative play and learning the Celestia mechanic is an interesting concept. It was noted that there are several stages that are necessary for space exploration that would work well in a game with this structure. Players must work their way from one place (on Earth with no space craft) to another location (Mars landing site).

[13] In Celestia, you board an aircraft with a team of adventurers to perform many trips through the cities of Celestia and recover their wonderful treasures. Your journey will not be safe, but you will attempt to be the richest adventurer by collecting the most precious treasures!

At the beginning of a journey, all players place their pawns within the aircraft; the players start the game with six cards in hand. At the beginning of each round, one player is chosen to be the captain of the trip and he rolls 2-4 dice to discover the challenges that they will face: fog, lightning bolts, killer birds, or pirates. He must then play the appropriate cards to continue on the journey and reach the next city. But before the captain plays the appropriate cards, each player must decide whether to stay within the aircraft:

• If you exit, you are guaranteed the victory points that come from exploring the current city.
• If you stay on board, you hope to make it to the next city in order to catch more precious treasures. If the captain can't overcome the challenge, though, everyone comes crashing down empty-handed and you'll need to begin a new trip with all passengers on board.

During the journey, each adventurer can try to pull out of the game with fabulous objects (a jetpack, astronomy glasses, etc.) or by changing the trip (modifying the travel or abandoning an explorer in the city). As soon as a player earns treasure worth at least fifty points, the game ends and this player wins. (boardgamegeek, 2015)

6.2 Game Concept Development

6.2.1 Game Play Analysis

The aim of the game will be to use a rocket to reach Mars, facing and overcoming obstacles along the way. There will be distinct stages, starting with building a rocket leading to take-off; travelling in space; orbiting Mars, and finally landing on the surface to finish and win the game.

Each of these stages will include aspects of 'real-world science and engineering issues' that the players will have to overcome as a team to build toward their Martian landing site. More detail on the gameplay development can be seen in section 7.0 (Testing and Discussion).

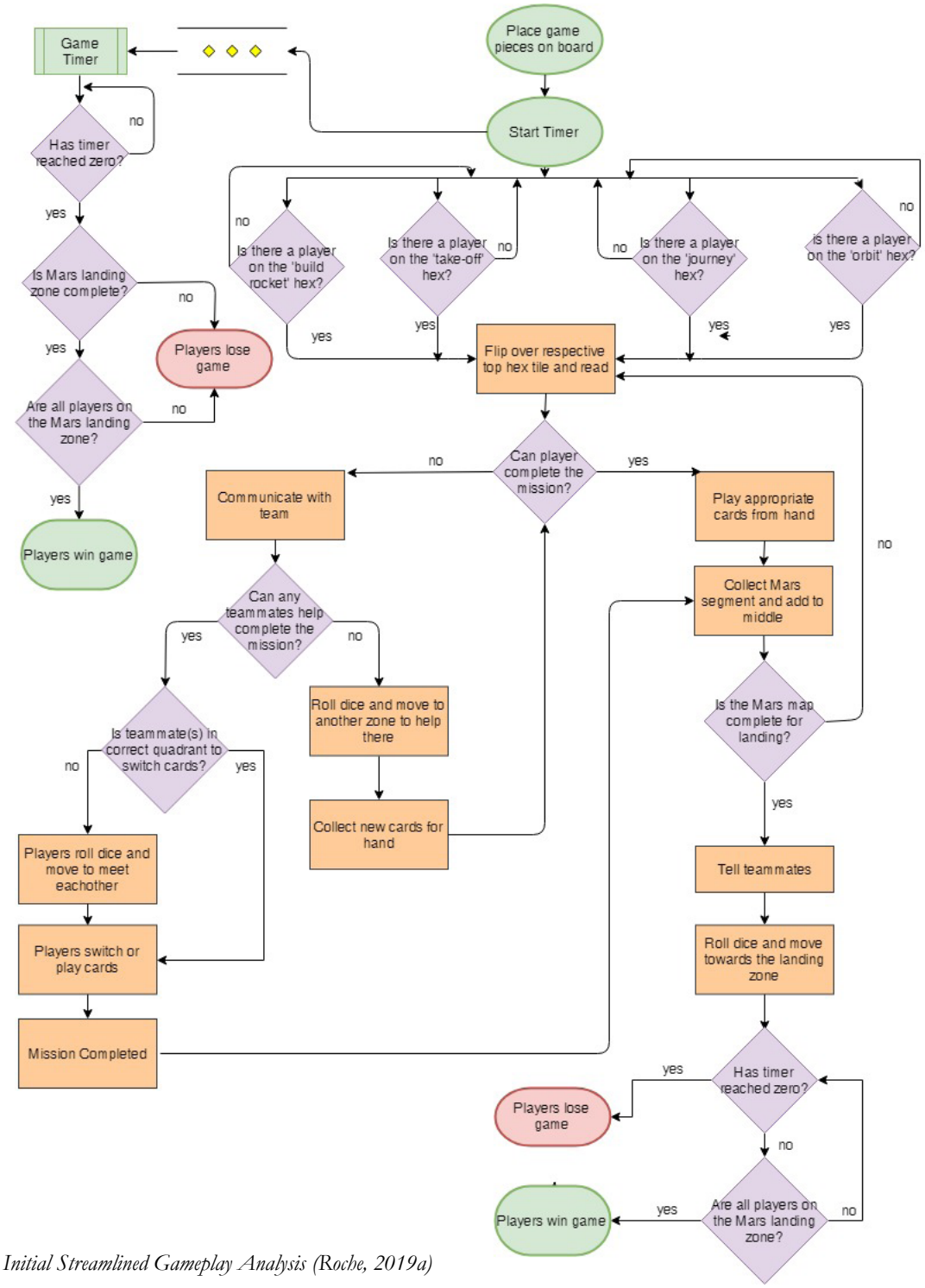


Figure 19 Initial Streamlined Gameplay Analysis (Roche, 2019a)

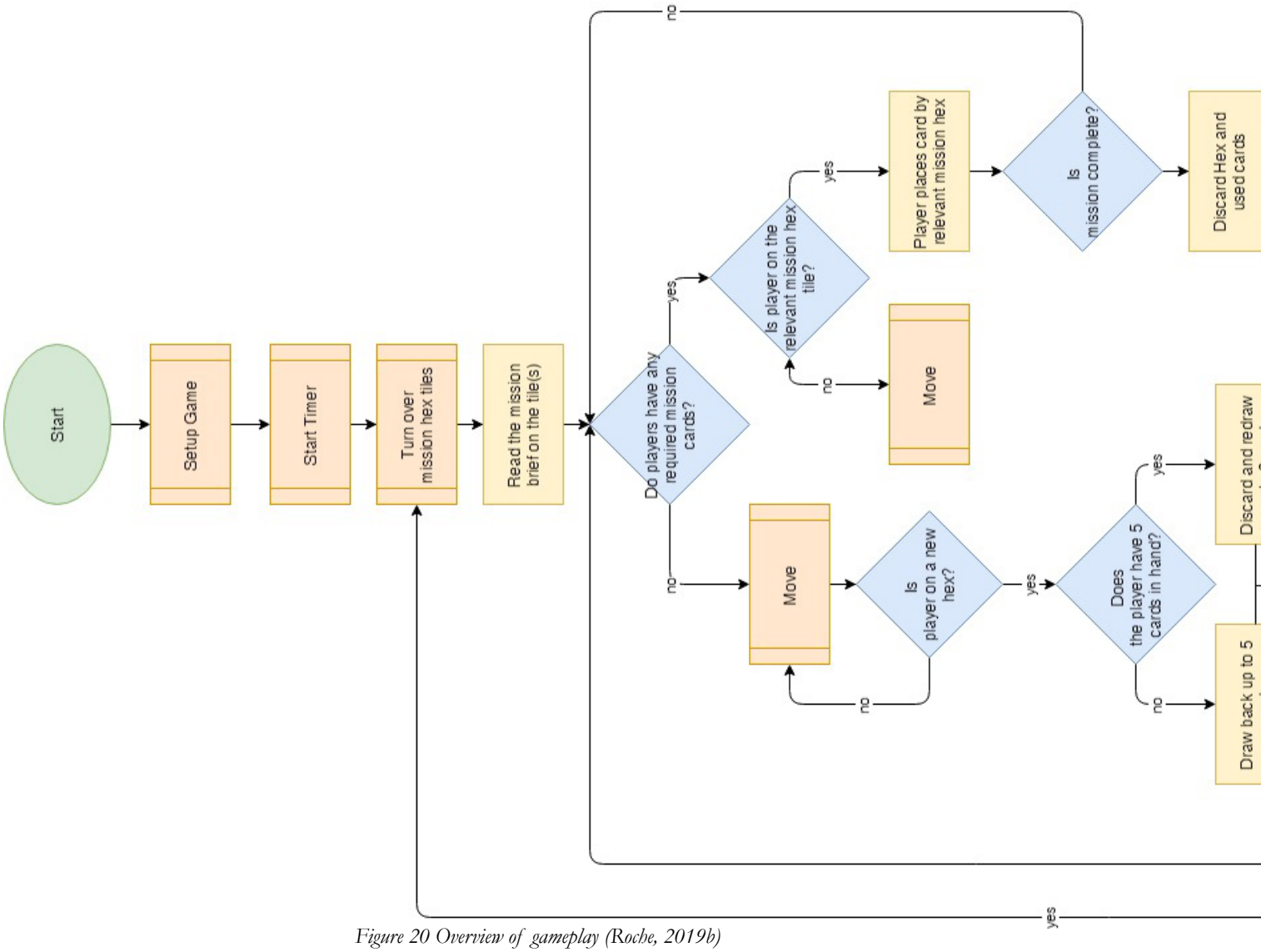


Figure 20 Overview of gameplay (Roche, 2019b)

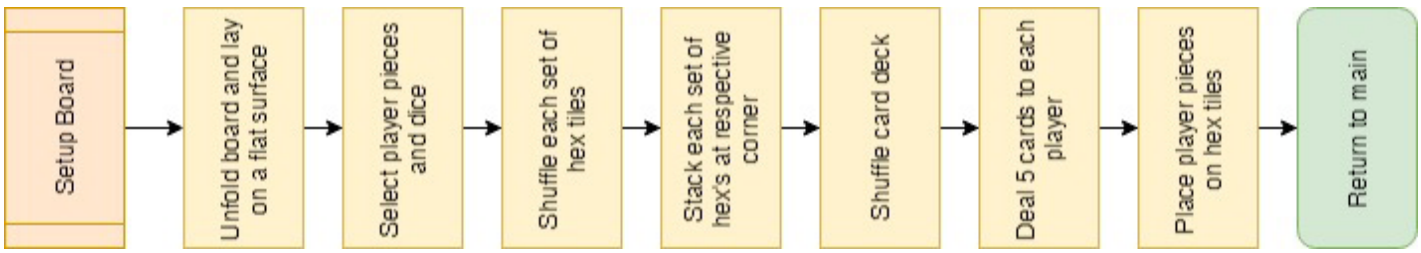
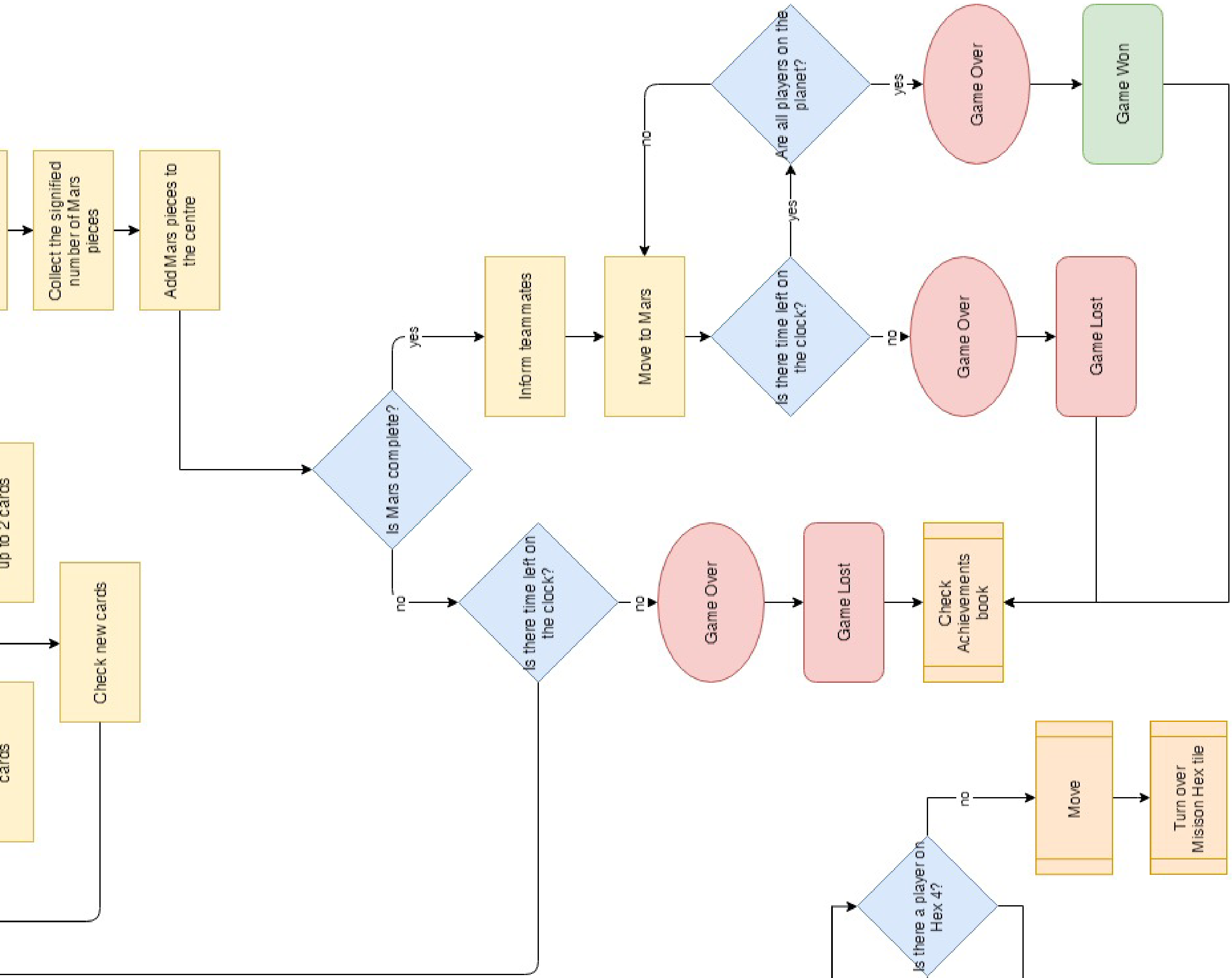


Figure 21 Process for game set-up (Roche, 2019c)



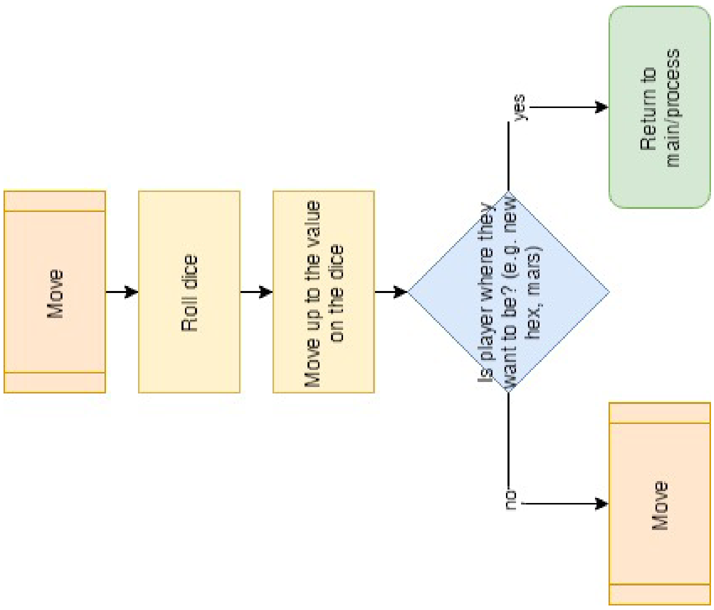


Figure 22 Turn over mission tile sub-process (Roche, 2019d)

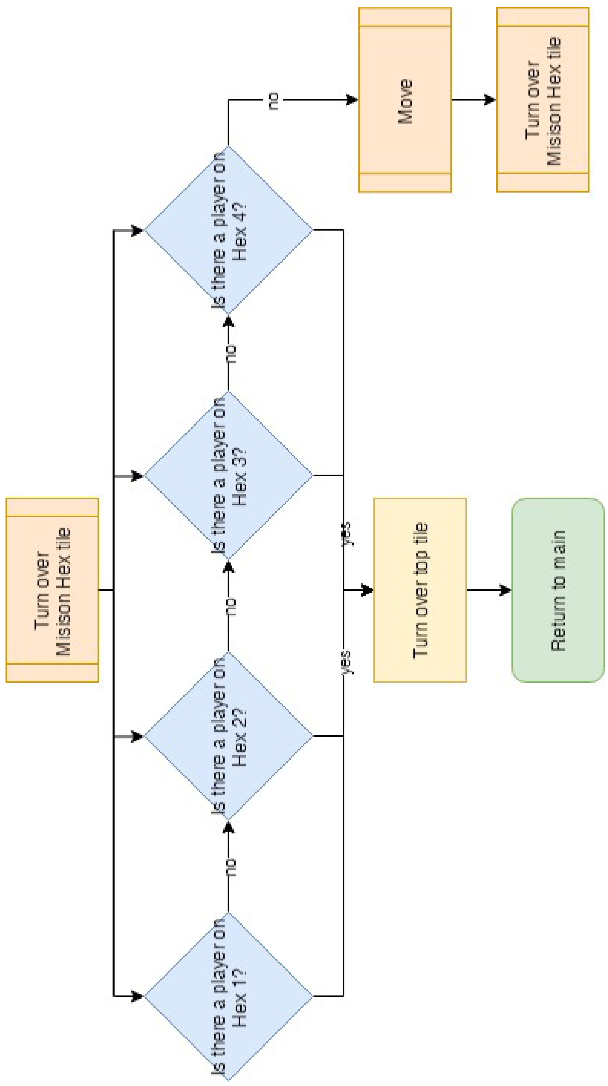
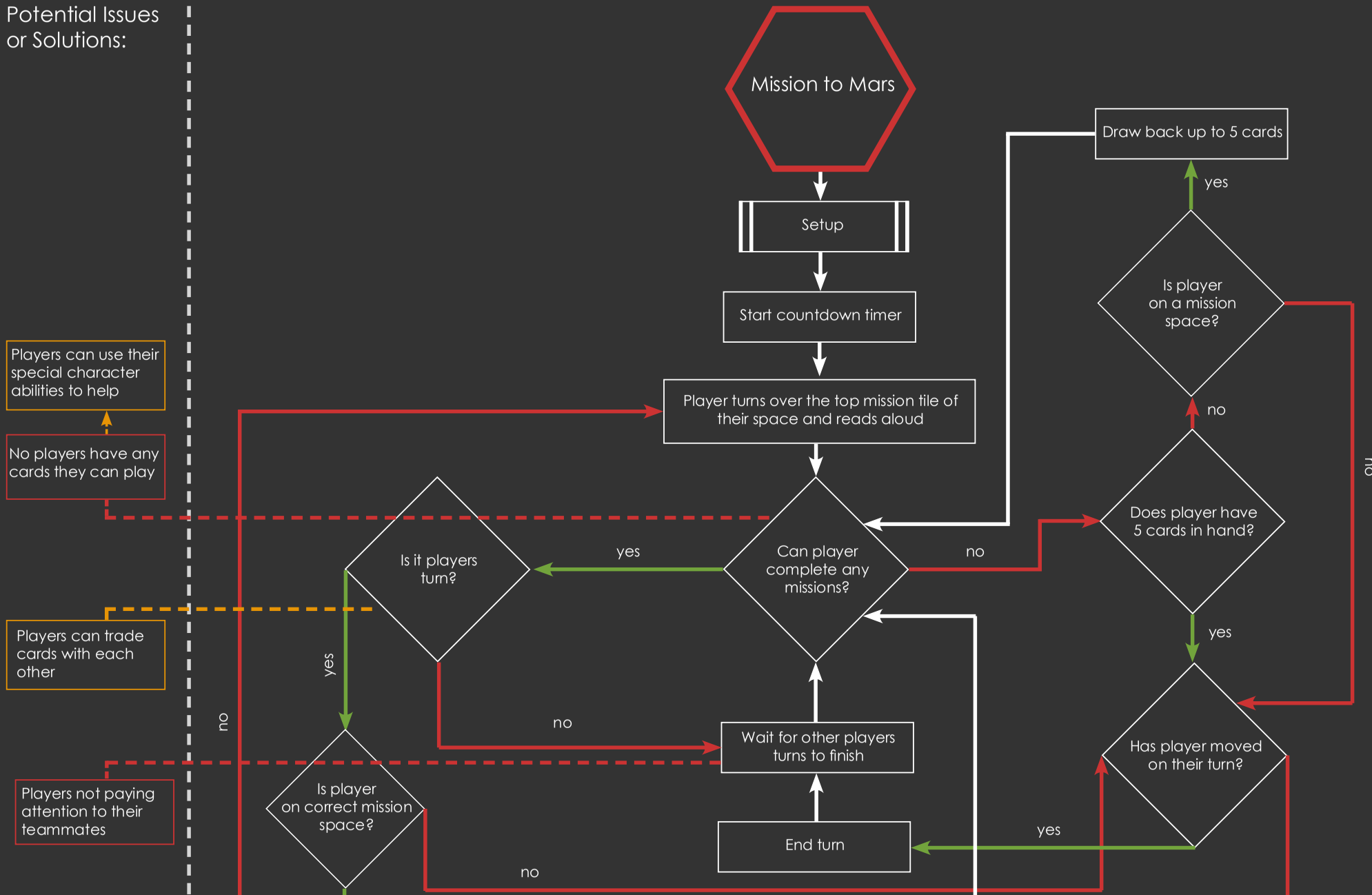


Figure 23 Movement sub-process (Roche, 2019e)


Potential Issues or Solutions:
Mission to Mars
Setup
Start countdown timer
Player turns over the top mission tile of their space and reads aloud
Can player complete any missions?
yes
Is it players turn?
yes
Is player on correct mission space?
no
Wait for other players turns to finish
no
End turn
no
Has player moved on their turn?
yes
Does player have 5 cards in hand?
yes
Is player on a mission space?
yes
Draw back up to 5 cards
no
Players can use their special character abilities to help
No players have any cards they can play
Players can trade cards with each other
Players not paying attention to their teammates

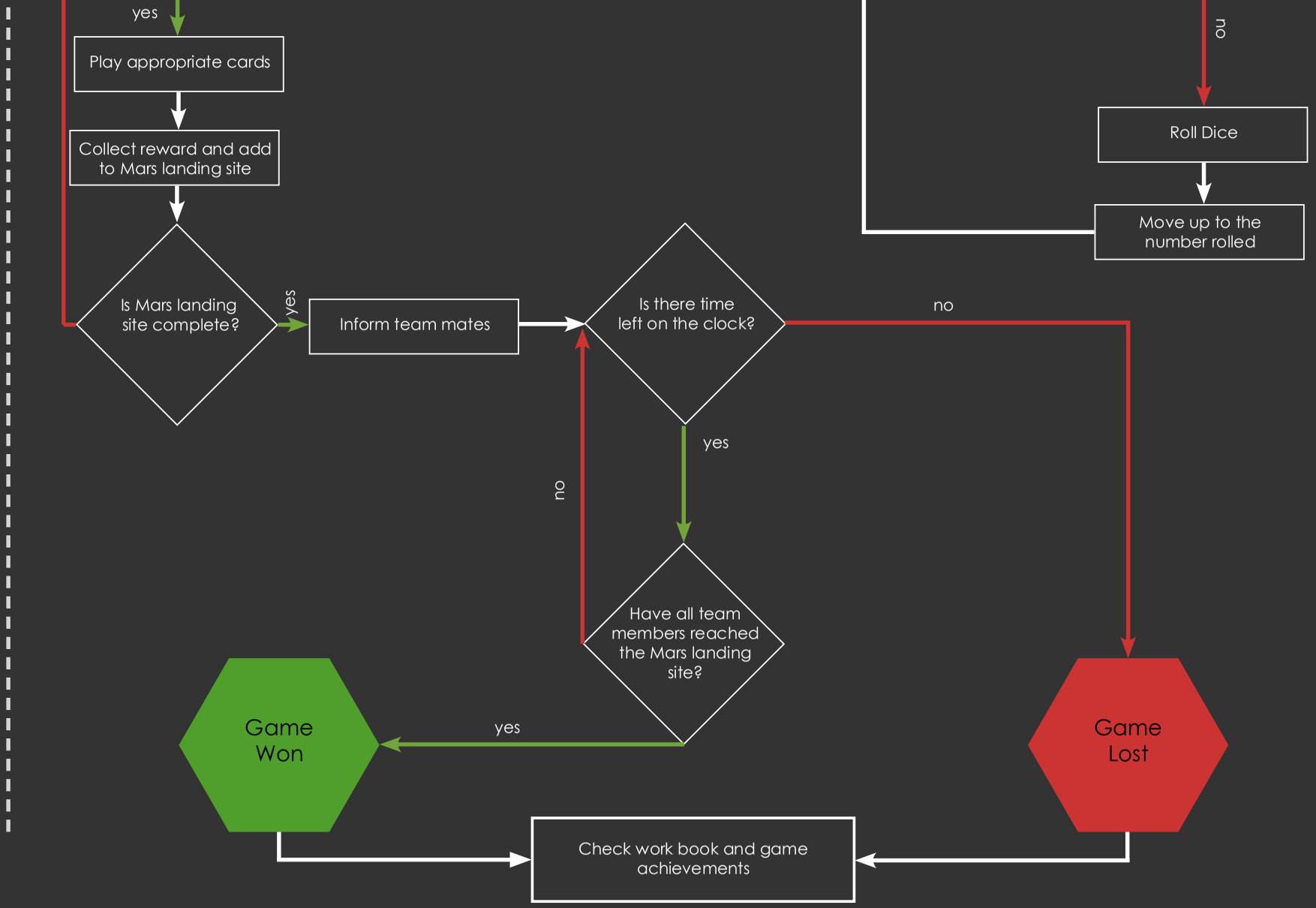


Figure 24 Final game play analysis (Roche, 2019g)

6.2.2 Potential Game Issues

Issue	Why might this issue arise?	Point of play	
Player not paying attention	Distractive classroom environment. Player grows bored. Player is confused by the game.	Other players turn	
Player leaving the game	Player going to the bathroom. Player having another activity to complete.	Any time	
Cards/Mission tiles being lost	Multiple users. Game moved between classrooms. Younger audience being less careful, e.g. dropping pieces or knocking the game over.	Game finished, putting away/moving	
No players having playable cards	The variety of missions and items needed for their completion being large. Small group of players having less options available then larger groups.	Mission completion	
Player/team cheating	Player/team wants to complete game with a victory. Players struggling with the game, e.g. are confused by the rules. Player disregard for game mechanics, educational content and skill development.	Card playing, movement, reward collection	
Board disturbed (pieces/tiles/cards fall)	Large number of people in the environment, people moving around and bumping into tables/chairs. Players getting up from the game table. Players reaching over the board to move/collect components.	Any time	

	Outcome	Potential resolution(s)
	Time wasted if they do not realise it is their turn. May not notice they have a card that can be played.	Other teammates keeping them focused. Making an engaging game - players are less likely to become bored.
	Game becomes more difficult for remaining players. Leaving players cards and ability go out of play.	Timer paused until player returns (if they are coming back). Leaving players cards divided amongst remaining players. Always start games with more than the minimum required players. Timer paused until player returns (if they are coming back). Players remaining cards divided amongst remaining team. Always start games with more than minimum required players.
	Game becomes more difficult due to restricted components.	Having spare/bonus components available. Providing online resources for download and production at school/home.
	Team becomes stuck and cannot play any further, game lost.	Give each player an ability that may help when they become stuck. Allow players to use a turn to discard and draw new cards.
	Players missing out on enjoyment. Players losing the educational value of playing. Players do not develop their wider skills. Players do not have a feeling of satisfaction after game completed.	Make sure rules are clear and not confusing. Have teachers monitor player behaviour. Include components that restrict players options, such as a card shoe for dealing.
	Loss of game progress. Loss of game components.	Components that fit into each other, such as Mars landing site and Mars sections. No tall/large components to game. Player returns board to how they remember it, otherwise return pieces to set-up locations, pausing while they reshuffle and deal again.

Table 8 Analysis of issues that may arise during game play

6.3 Design Research

Many of the same pieces of research were used in this stage as for the branding research (appendix section 4.2). A mood board (figure 25) was created near the start of the project to be used as a reference point and inspiration for the game design look and feel.

Another source of inspiration for the products design is the book *Illuminae*[14] (figure 26) by Jay Kristoff, aimed at a similar audience and using a variety of graphics to tell a story.

[14] *The Illuminae Files* are a trilogy of sci-fi books for teenagers, by authors Jay Kristoff and Amie Kaufman, originally published 20 October 2015

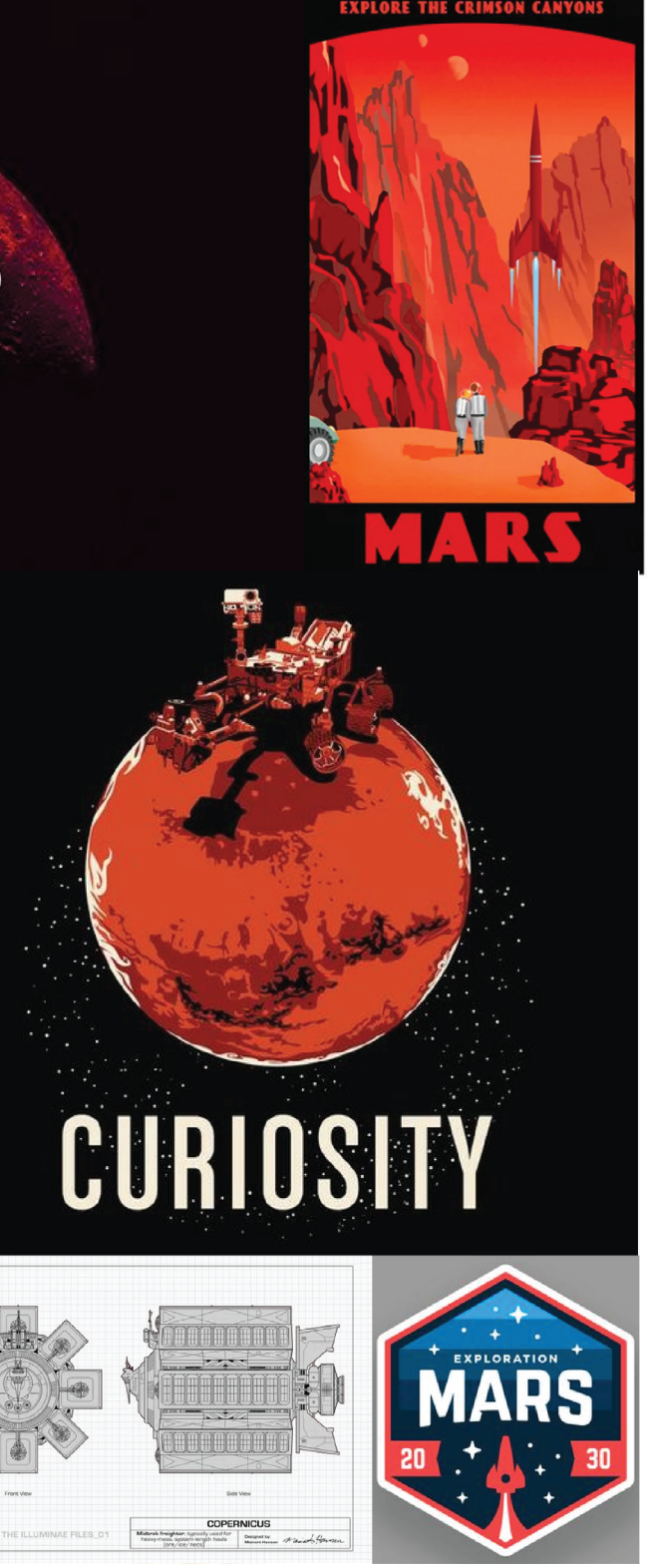
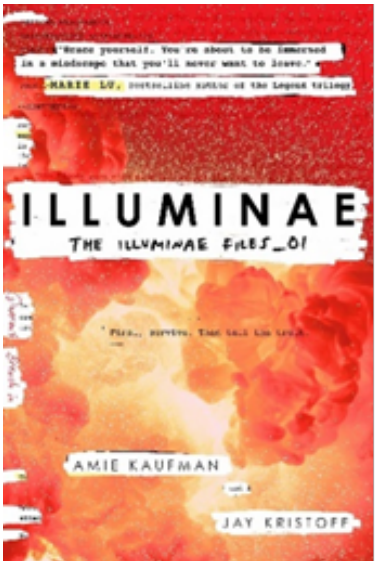
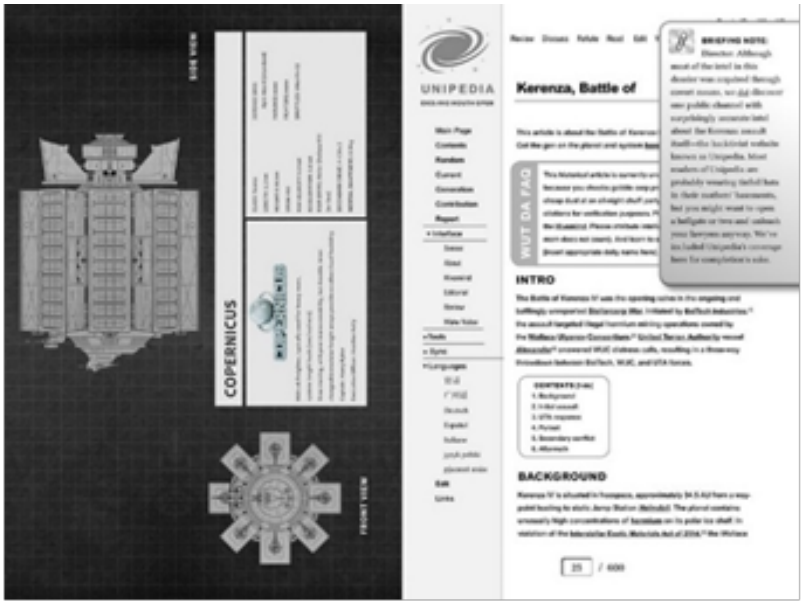


Figure 25 Mission to Mars project Mood board (Roche, 2018)





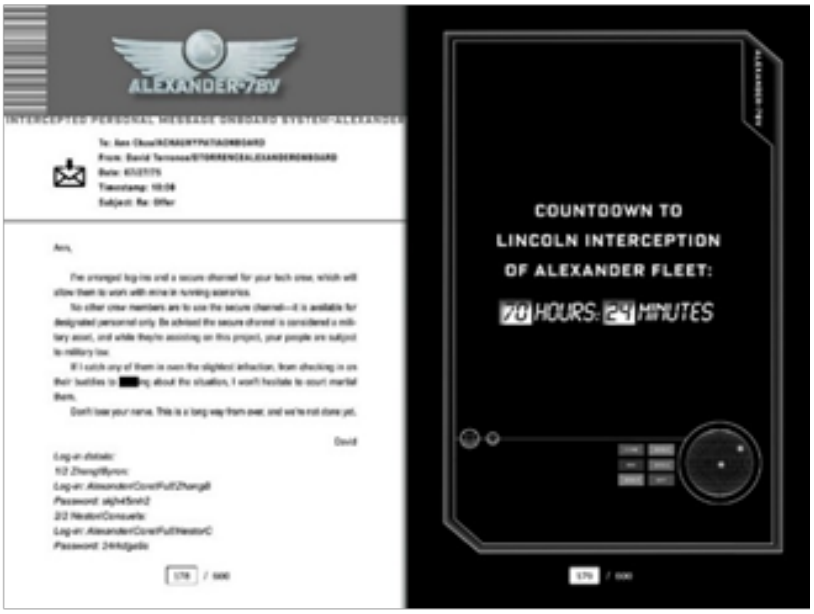


Figure 26 Illuminae book cover and graphics (Kaufman & Kristoff, 2015)

6.4 Design Ideation

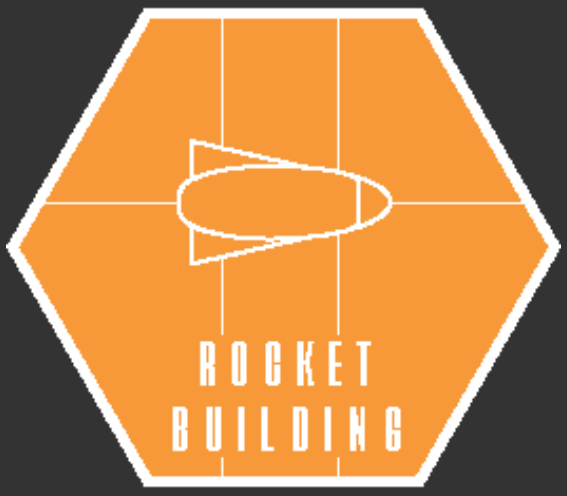


Figure 27 Stage One Tile idea (Roche, 2018a)

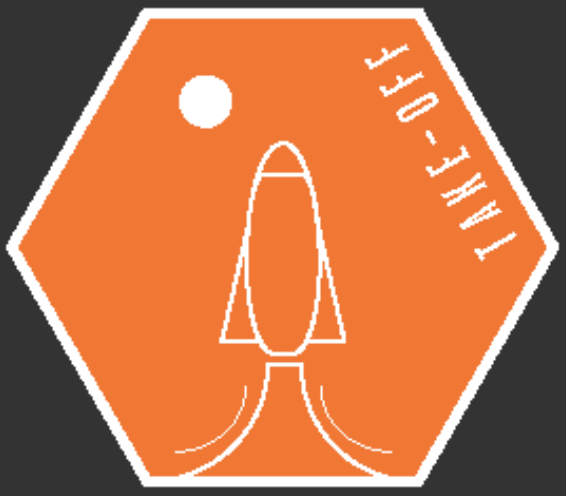


Figure 28 Stage 2 Tile idea (Roche, 2018b)

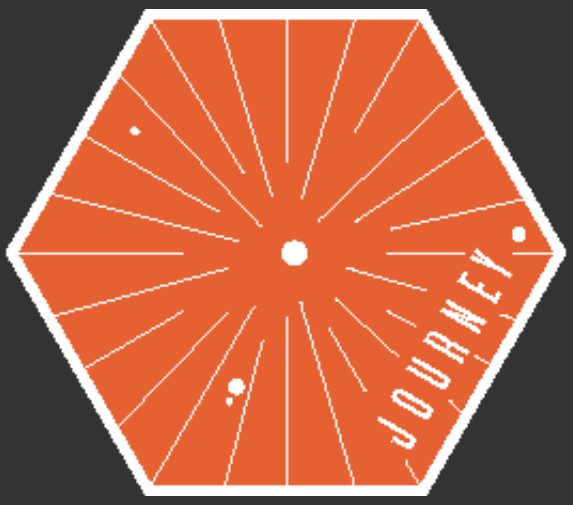


Figure 29 Stage 3 Tile idea (Roche, 2018c)

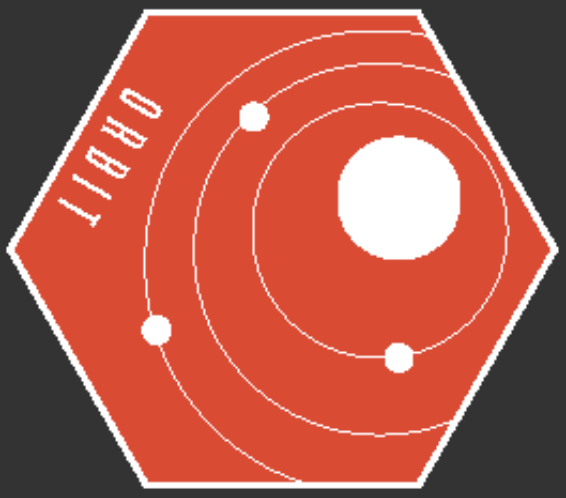


Figure 30 Stage 4 Tile idea (Roche, 2018d)

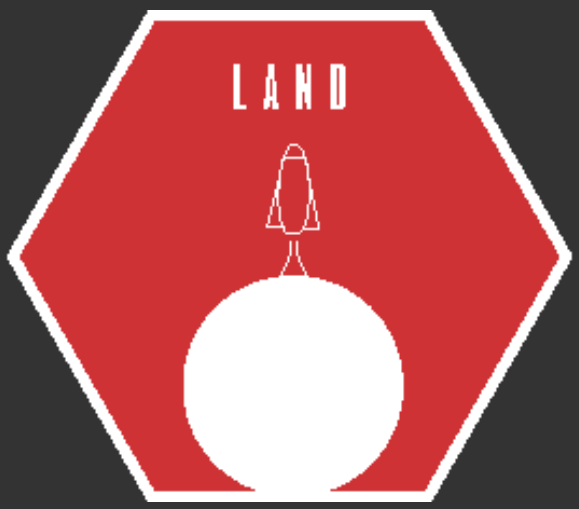


Figure 31 Stage 5 Tile ideation (Roche, 2018e)

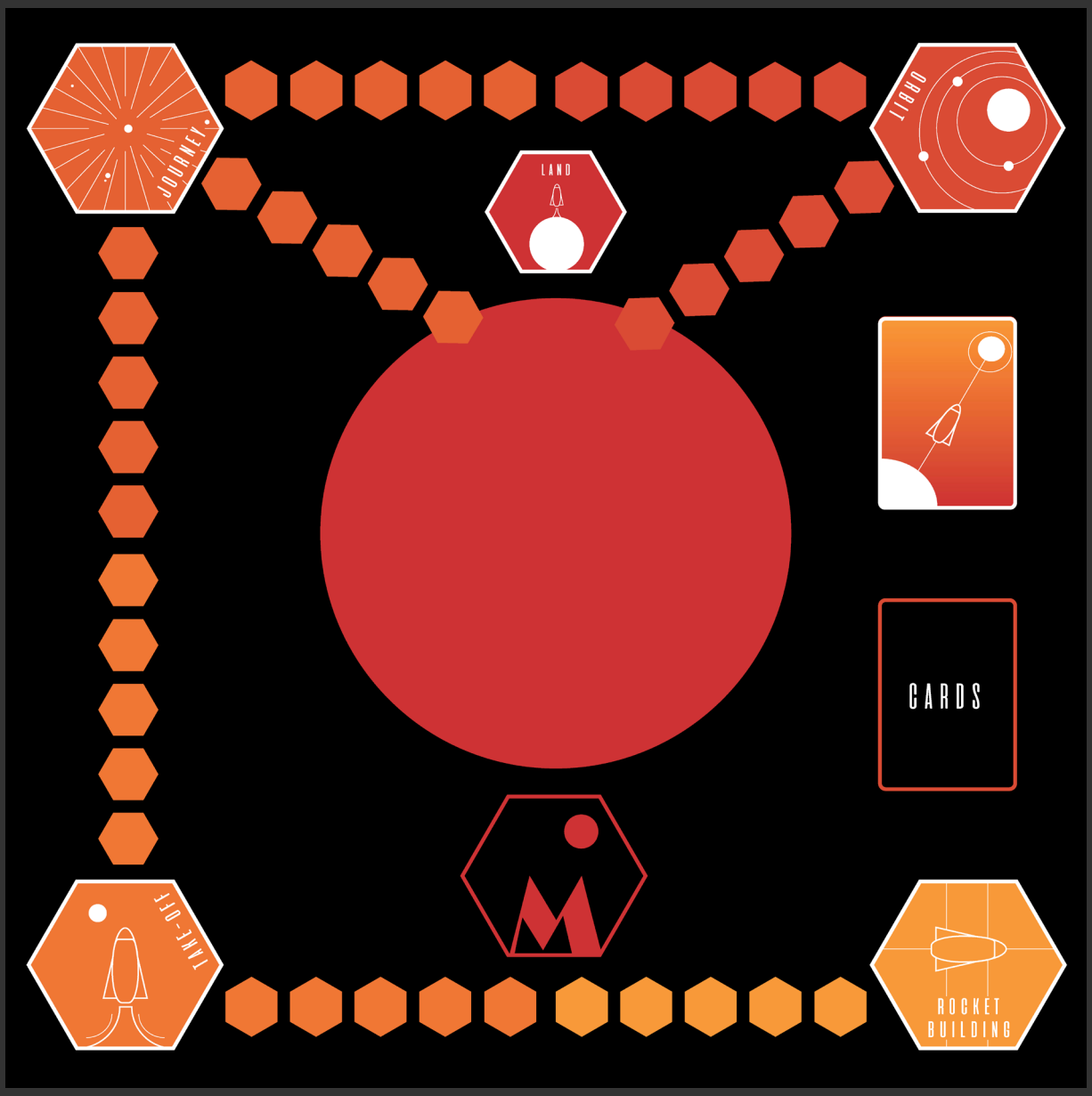


Figure 32 Game Board ideation (Roche, 2019f)

6.5 Graphic Design Development

6.5.1 Font Selection

The font that has been chosen for the main body text throughout this product (including on game cards and rule book), is Century Gothic as shown in figure 33.

This font was selected because it is easy to read. There is clear kerning between each letter and this spacing makes it easier to read, especially for those with difficulties such as dyslexia. Another reason to choose Century Gothic is the letter forms it uses, for example the lower-case letter 'a', which can be seen in figure 33, is formed in the way that children are initially taught in school when learning the alphabet. The font is both simple and accessible while still conveying a science-fiction and space vibe.

It is a widely available font, which makes it easier to use and means there are a variety of effects (e.g. bold) that can be applied to it.

6.5.2 Card Development

During initial game development cards were made with a colour code system and the facts for them were sourced. However initial playtesting showed that players did not instinctively know the colour code system, having to play a couple of turns before understanding it. They also disliked the font, which was difficult to read. Typical board game cards use size 9 font however, to make them slightly easier to read size 10 font has been used on all card iterations. Having colour to the edge of the card also meant that players could potential cheat by looking at the card edges as they drew.

The second development of the cards kept the colour coding system but made it easier to understand with a clear direction at the top of what the card was. While this was an improvement, the card title and fact lengths were constantly changing; and the lack of consistency was not very aesthetically pleasing. While the font used was easier to read the spacing was strange and unsuitable for the card shape. The text also began too close to the line, looking very tight on the left-hand side. The lines were adapted, and hexagons were added to the design, incorporating an element consistent to the M2M brand.

The final card design makes use of the font described in section 6.5.1 and moves the card title to a consistent location. The facts all start at the same point on the card, leaving a space for potential illustrations in the future. The lines were once again slimmed down, but the colour coding and card identifier remain.

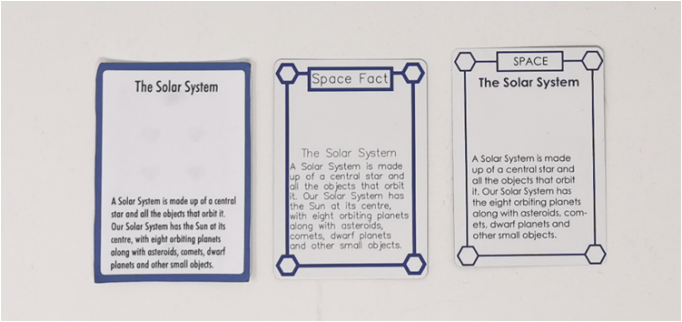


Figure 34 Development of the solar system fact card design

Figure 35 Example item card final design

The font that will be used for this project is Century Gothic.
Aa Bb Cc Dd Ee Ff Gg Hh Ii Jj Kk Ll Mm Nn Oo Pp Qq Rr Ss Tt Uu Vv Ww Xx Yy Zz 1 2 3 4 5 6 7 8 9

Figure 33 Century Gothic selected font

6.6 Game Reward System

6.6.1 Reward System Theory

For the game to be effective as an educational tool it must also be challenging, as this will lead to discussion, asking questions and learning. However, a challenging game will be more difficult to complete successfully and, for some players there is the potential that they could become discouraged if they fail to complete the game successfully.

One way to avoid children growing disappointed or discouraged when they do not manage to beat the game is to use a rewards system. Many video games use a rewards system, e.g. Xbox's 'achievements' and PlayStation's 'trophies', that are rewarded in relation to completion of tasks during play.

In order to make users feel like they have achieved something by playing the game, even if they have lost, they would have accomplishment books. After they have finished a playthrough they can look through the book to see what tasks they have completed and mark them off. The concept could be expanded to include some form of physical reward for completing a set page or number of achievements.

This would also give students their own piece of the game, which they could take home with them and refer to at any time. Not only could this reduce demotivation from losing, it could also motivate or encourage children to play the game again, experimenting with different methods of play so that they can complete certain achievements that have yet to be marked off in their book.

6.6.2 Reward Ideation

An issue that arose during playtesting (section 7.1) was how to ensure students took the time to learn the various facts and information the game provides. After some consideration it was decided that achievements would be part of a larger workbook that includes activities related to the games content. Both completion of tasks during the game and the books activities would result in player 'experience points', allowing them to be promoted up the ranks from 'space cadets' to 'commanders'. Although this has been considered at this stage in the project, it is more suited to future work and is discussed further as a concept in section 8.1.5.

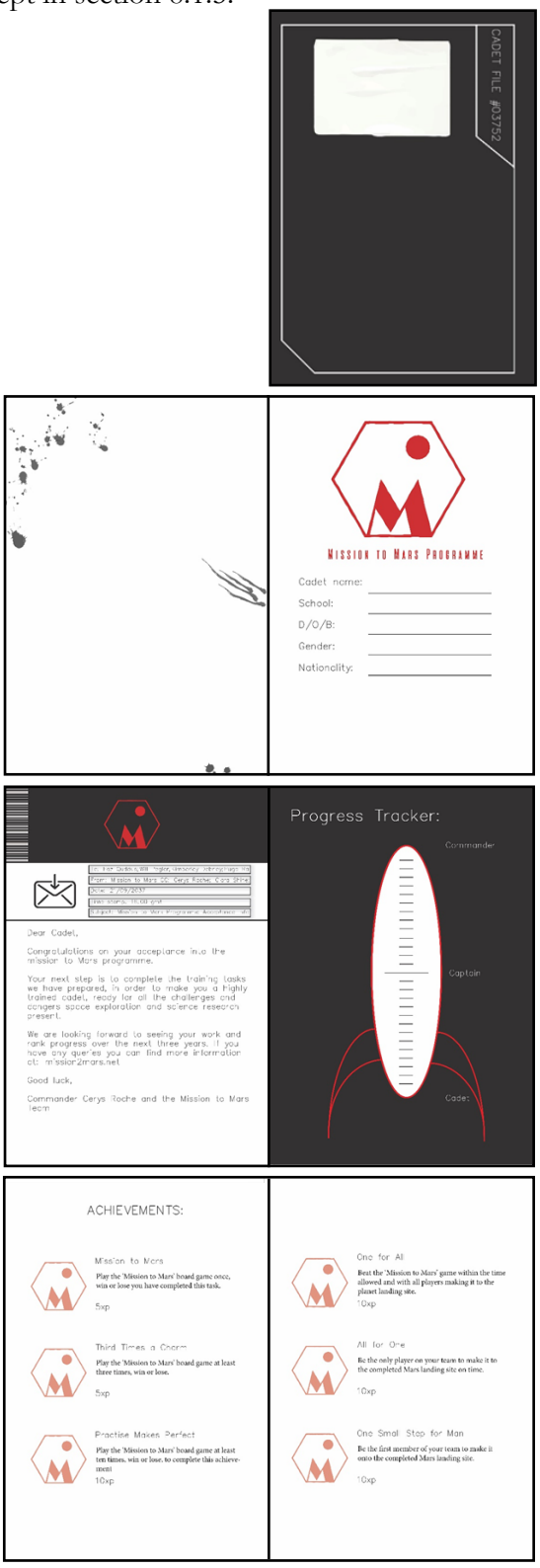


Figure 36 Workbook front cover
Figure 37 Workbook student information page
Figure 38 Workbook introduction page and experience tracker
Figure 39 Example of gameplay achievements in workbook

6.7 Final Game Design

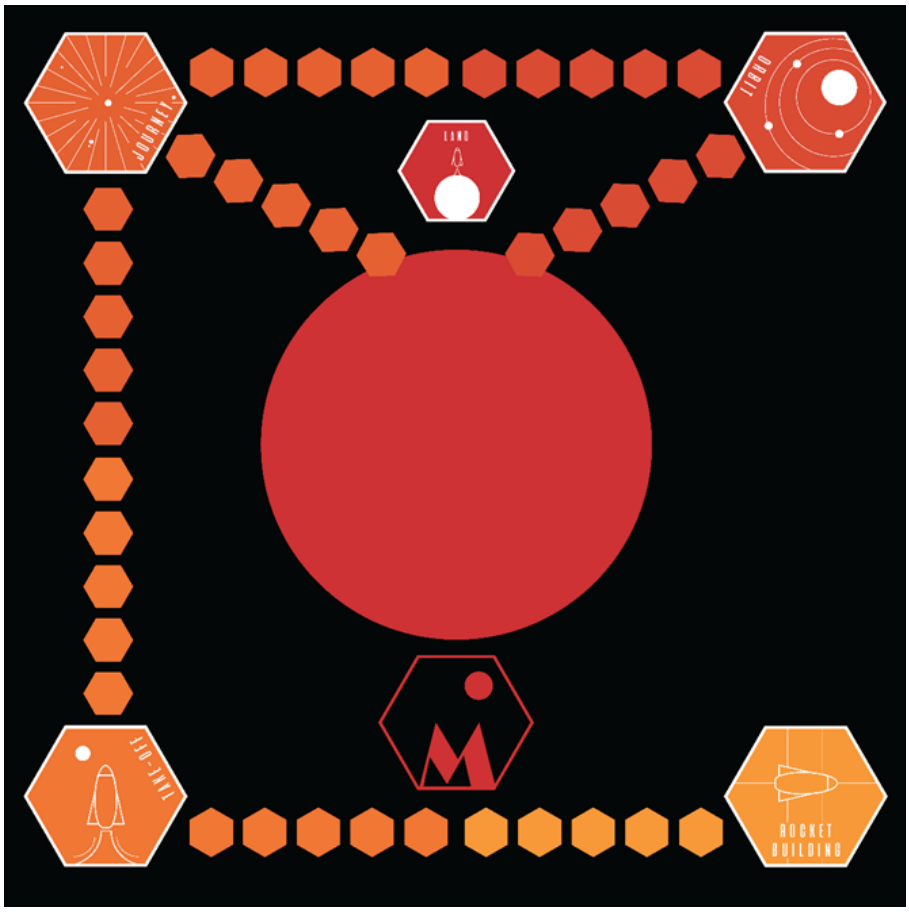


Figure 40 Final Game Board Design (removal of card place signifier and improvement of spacing) (Roche, 2019h)

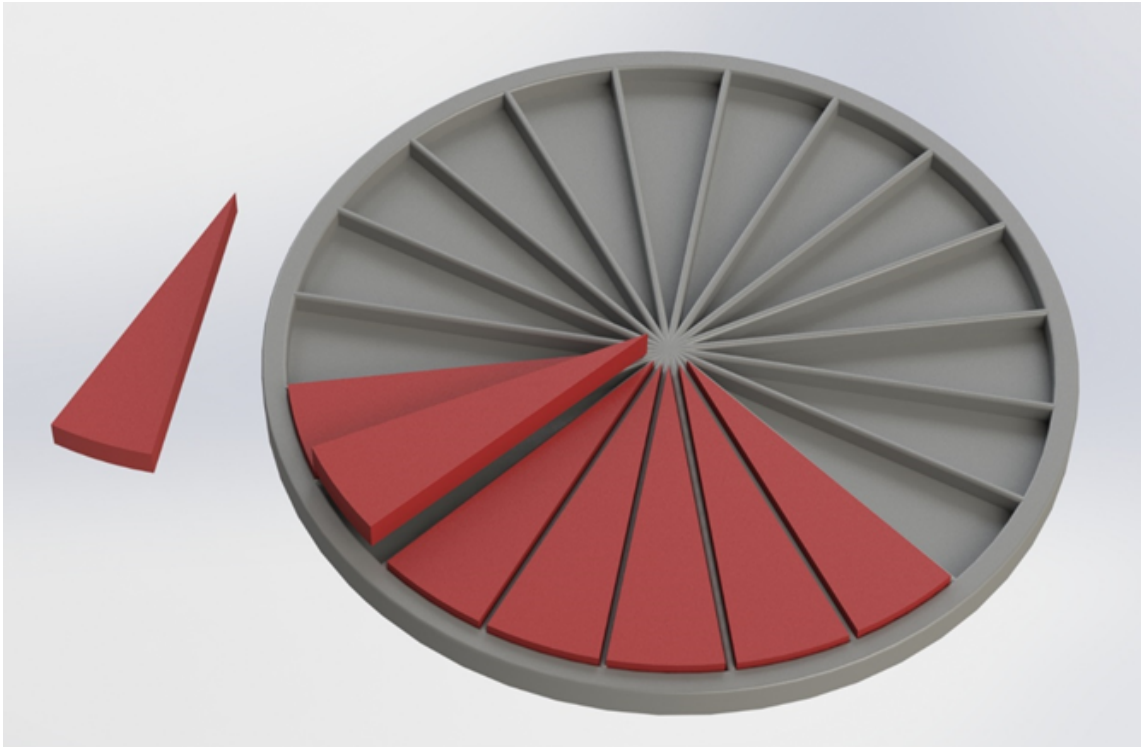


Figure 41 Render of Mars game centre and Mars slices (Roche, 2019i)

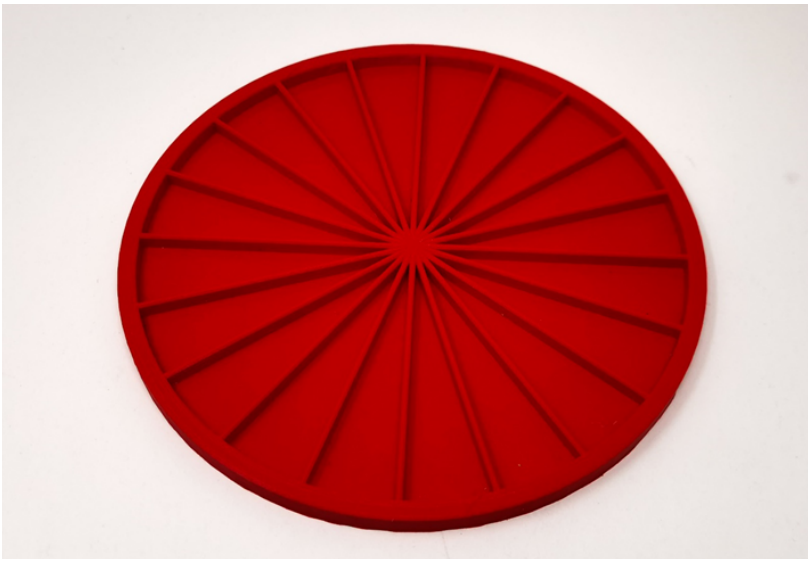


Figure 42 3D print of the central Mars landing site section (Roche, 2019j)

Figure 43 Example game board set up (Roche, 2019k)

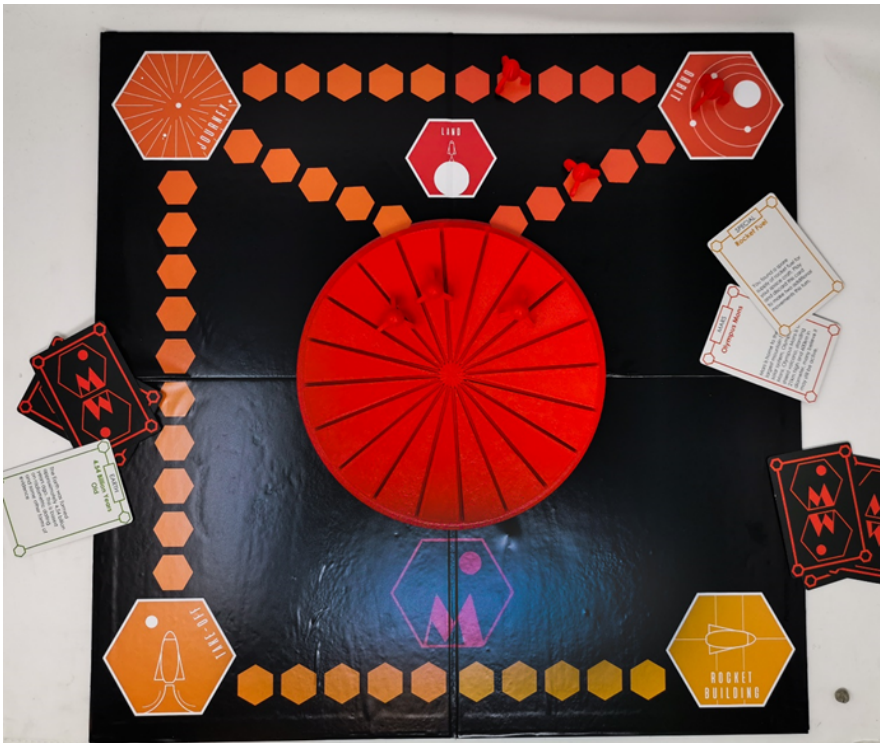


Figure 44 Completed Mars game board (Roche, 2019k)

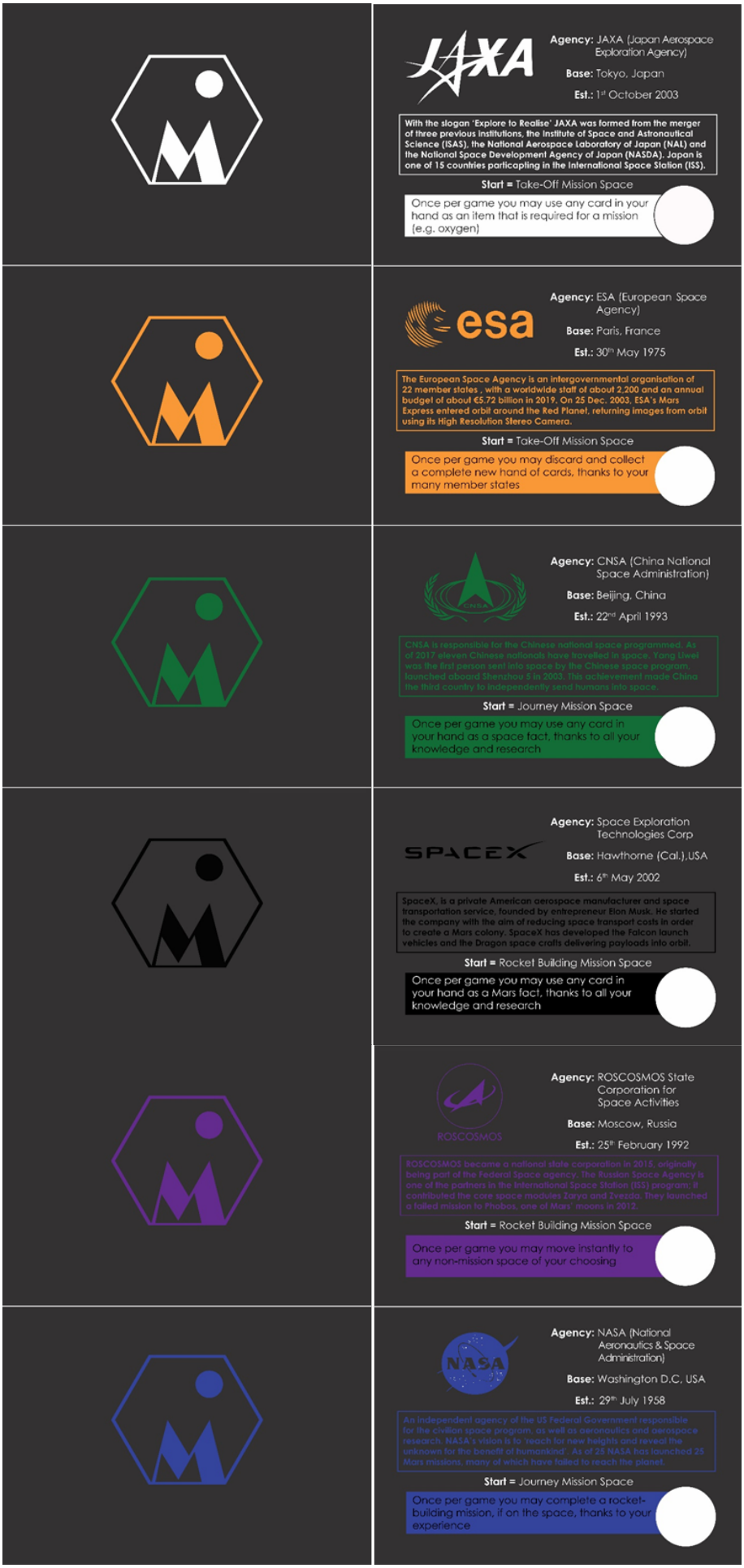


Figure 45 The information/ID cards for the games six player characters (Roche, 2019l)

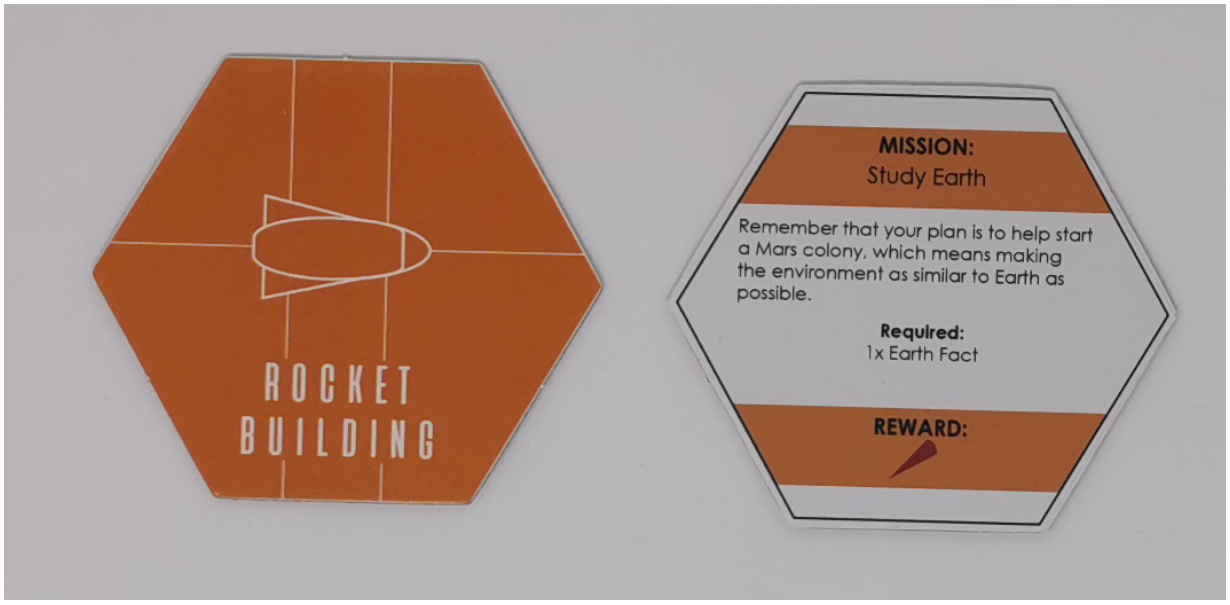


Figure 46 Game Mission tiles (Roche, 2019k)

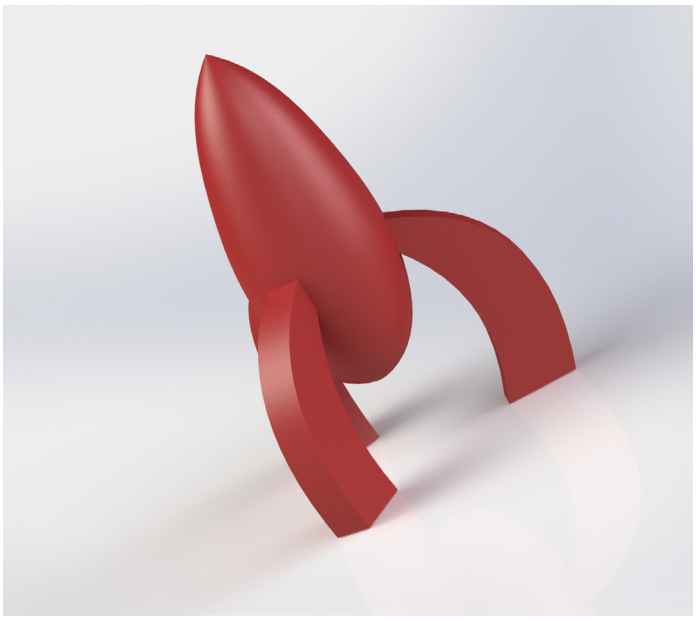


Figure 47 Player piece CAD render (Roche, 2019m)

Figure 48 Player pieces (Roche, 2019k)

6.8 Additional Design Aspects

Mission to Mars

YEAR GROUP 7

Teachers notes

20-30 minutes

Learning Objectives

- To understand the various elements of space travel
- To work and communicate effectively as a team
- Learn about Earth and Mars

Overview

The game aims to help students learn about the science and technology involved in a mission to Mars. As they work together to complete missions, within a set time, to reach the planet.

Success Criteria

- I can work as part of a team
- I can state facts about the planet Mars
- I can state facts about Earth
- I understand and can describe the various aspects of space travel/crafts

Introduction

The purpose of this activity is to look into the **future of space exploration**. Ask the students what they think the next steps in space exploration are. Discuss the idea of **Mars colonisation** and the potential reasons for this (mention **over population, resource depletion, environmental disasters**)

Resources:

1. Mission to Mars game box (per group)
2. Stop-watch/Timer (per group or class)

Activity 1: Shallow Task Game Setup

- **Teacher controls** the **formation of mixed ability groups** sized 3-6 (preferably **4-5 per team**)
- Learners remove game pieces from the box, layout board, **shuffle** the **deck** and deal 5 card each, place remaining cards in the dealing shoe/shoot
- **Shuffle the mission tiles** and place them at there respective corners
- Each learner **selects a player piece** and reads the respective information card for that piece/colour
- **Timer setup** to approx. 15 minutes (normal)

Activity 2: Deep Task Game Play

Student led group game play:
Learners to play the game, monitored by teacher, for about 15 minutes

Activity 2: Profound Task Discussion

1. Have the groups **discuss** their **success/failures** together, why did they win/lose. Ask **what went right/wrong** and what could have been improved.
2. Have teams discuss their differing experiences.

Rules

- Players go **one at a time**, they can play as many cards as they like but may only **move once per turn**
- Players may move up to the number rolled on their dice
- Players can **trade cards** if they are on the same or adjacent spaces
- Players can only have **5 cards in their hand** at any time, new cards can be collected when the player lands on a mission space
- Only **one mission per section** (e.g. take-off) can be active at a time
- Cards can be played individually, placed next to the mission tile until all tasks are complete

To win: All players must be on a completed Mars before time runs out

Curriculum Links

Composition of the **atmosphere** and air as a source of oxygen and nitrogen (DA 2.4 H, DA 2.4 C, AS 1.3.2 C, AS 1.3.2 D)

The main features of our **solar system** (AS 6.4 A, AS 6.4 B)

Understanding what **elements and compounds** are (DA 2.1 A, DA 2.1 C)

Newtons laws of motion (DA 6.2 A)

Understanding **forces** such as thrust and gravity, e.g. weight vs. mass W=mg (DA 6.2 E)

LNF & DCF

Literacy - reading the facts and on the cards, science

Numeracy - rolling dice and moving pieces, being aware of the timer and time remaining

Digital - Learners go to mission2mars.net

Wider skills - teamwork, problem solving, leadership, communication

Differentiation & Pupil Support

- Game **time variations** available, set timer to 10 minutes to make it more difficult or 20 to make it easier
- Students can access support at mission2mars.net

Figure 49 Teacher lesson plan for Mission to Mars, based on lesson plans by Angela Darke (shown in figure 3, section 2.2)(Roche, 2019n)

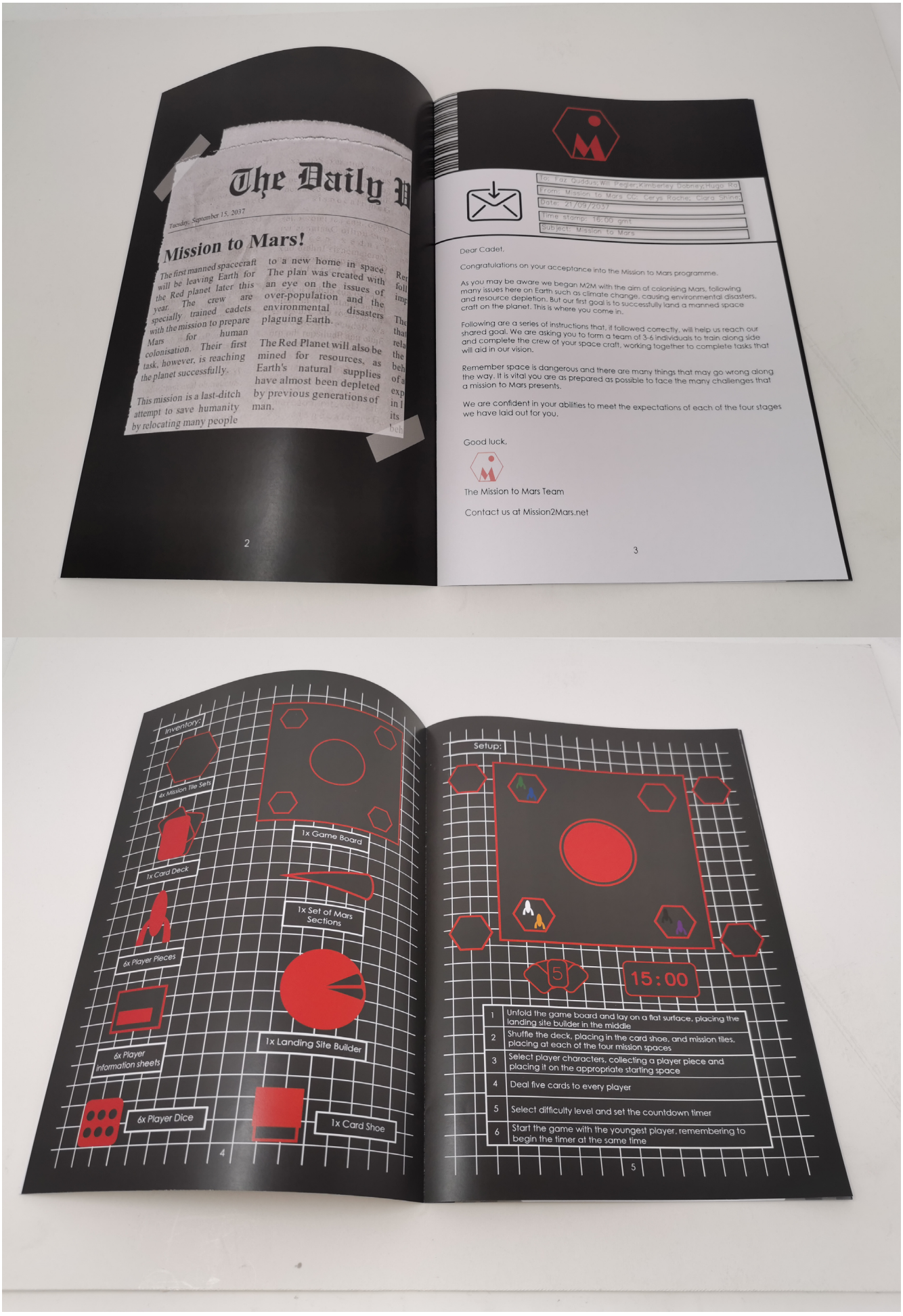


Figure 50 Game instruction manual (Roche, 2019o)

7.0 TESTING AND DISCUSSION

7.1 Play Testing

Play testing was carried out in order to gain a clearer understanding of how players may approach the game. Playtesting at different stages also helps ensure the best rules and game mechanics are utilised in the final product. This is discussed further in sections 7.2 (Game Balancing) and 7.3 (Game Adaptations).

Several play-testing sessions were carried out with a range of users. To ensure consistency each player was given a participation information sheet (appendix figure 7.1) and provided the opportunity to ask the supervisor any questions they may have. After this they were asked to sign consent forms and given a rule book along with all required components for the game. At any time they were allowed to ask questions to the supervisor and their game play was recorded for future reference.

The findings from these playtesting sessions are discussed in sections 7.1.1, 7.1.2 and 7.1.3. For all sessions gameplay was observed and notes made on player comments, positive game aspects and any issues that arose (including player confusion and errors). After playing the game feedback was provided by each player independently before evolving into group discussion of their experience.

7.1.1 Session One

The first play testing session was conducted with four players, all of whom were university students. They played the game in real-time, with all players being able to move and play cards simultaneously. This resulted in a victory, beating the game in a time of 8 minutes. The simultaneous play method caused a slightly chaotic environment, as players found there was too much going on at once and hence, they lost track of dice rolls and other people's moves. This also led to divided communication within the group, with players pairing off to complete missions and there being little cross communication between sides.

Overall the players believed the mission completion and Mars building game mechanics were easy to follow and understand and did not want the game to lose its fast-paced elements. They responded well to the interesting collection of facts but wondered if there was a way of ensuring the players learnt these. The team enjoyed the game and approved of the board's colour schemed quadrants, but thought communication and learning would improve if players took turns one at a time (as per traditional game playing methods).

7.1.2 Session Two

As with the first play testing session, a team of four different university students were asked to play the game. This time players were asked to take individual turns, only moving once per round. This team failed to complete enough missions in the time available and were observed to grow distracted during gameplay, especially when awaiting their next turn or if they had no useful cards.

Players enjoyed the elements of teamwork, primarily the ability to trade cards, but felt restricted in movements suggesting the addition of higher value or multiple dice for players. They discussed the use of a purpose-built central portion (section 6.7 figure 41) for collating the Mars pieces they had won, which they also believed would make it clearer how many they needed to collect.

Another issue that arose was the fact they could see the border of the card that they were collecting, which they believed could lead to children cheating. This response led to adapting the card design (section 6.5.2) along with the consideration of a dealing shoe (to store and deal cards from) or card holder.

Once again, players found themselves interested in the facts and wanted to read them, but raised the concern of how to ensure these were learnt. Discussion associated to this can be seen in section 6.6.2 and the potential development of a related work book (section 8.1.5).

7.1.3 Session Three

This was the only session to use all the proposed deliverables for the game, including the central Mars landing site components, player agency characters and card shoe. This group also consisted of four players. However, they were asked to play the game three times in a row at the medium difficulty, meaning they had 15 minutes to build their landing site and reach Mars together safely.

It was recommended that they took the first playthrough as a practise run, playing slowly and coming to grips with the game mechanics and requirements. During this attempt the team did not complete the game, being encouraged afterwards to discuss what they had just played, explaining to each other how they might best attempt their second go.

The second game led to a victory, with all players reaching a completed landing site at 12 minutes. Only one player felt the need to use their special player ability (gaining a bonus Mars piece) but, unlike other sessions, they did not trade cards with each other at any time. Another player felt unhappy because they had only been able to contribute one card to completing the missions, but others encouraged them by saying it had been useful them travelling further around the board to discover the higher-level missions.

During their third play-through the team became stuck, until a player remembered they all had their special abilities to use. This game saw all four players use their abilities and two instances of card trading, with victory achieved just before 15 minutes. Afterwards players responded that they had enjoyed the slightly rushed feeling at the end of the game as they all raced to make it to Mars in time.

This team all agreed that they struggled in the first round of gameplay, while trying to understand the rules, doubting that many players would find victory during their first session. However, they found that once they understood the rules their enjoyment and communication drastically improved. They agreed that this made sense as a length of time for a medium level difficulty as a younger audience may need more time for communication and reading than they did, so a longer 20-minute time limit would be useful during initial play sessions.

Players felt proud when they could contribute and believed having each player's special ability as an option was an important addition, helping them out when they were struggling and giving each player a sense of individualism while helping their team. The team thought they did not trade many cards as their communication was not always good enough. There were moments when they expected it would have been beneficial but were not aware enough to notice the possibility.

One improvement they did suggest was the ability to collect new cards every time it was their turn rather than just when they reached a mission space.

7.2 Game Balancing

Originally the card deck was designed with just enough of the correct cards to complete every mission. After some consideration, based on playtesting results, some additional cards (of all varieties) were added to the deck. There are four main types of player cards:

- Mars facts
- Earth facts
- Space facts
- Item cards

Bonus special ability cards were also introduced following play testing feedback, allowing players to make alternative or additional moves.

A feature added after the first two play testing sessions was the player characters. Instead of each player choosing a colour, the colour also associated to a real-life space agency. This granted each player the chance to use a set special ability once per game, potentially allowing for a sense of individual usefulness. Player components can be seen in figure 51.

Figure 51 All player agency character components (Roche, 2019p)

7.3 Game Adaptations

Following playtesting some of the games original rules were adapted to be more appropriate for the required gameplay. These included moving away from all players going at once (7.1.1 Play Testing Session 1) to players taking turns (7.1.2 Play Testing Session 2), to create a less hectic environment and increase time pressure and quality of communication. Players are also able to draw back to five cards when they land on any mission space, whereas originally they only collected two new cards.

User considerations led to a few new components being added to the game. First a Mars centre piece that the 3D Mars slices could be fitted into. This was felt to provide a more satisfying interaction and made it clearer to the players how many "slices" they needed to earn.

Secondly a dealing shoe for the card deck decreases the ability of players to cheat and should also help prevent loss of cards over multiple play sessions.

Finally, player characters were added, with each player piece being linked to a particular space agency rather than just being a different colour. This provides players with a better sense of connectivity and allowed for them each to have a special ability they could use once per game.

8.0 CONCLUSION

Over the course of eight-months this project has taken the issue of poor engagement and enthusiasm for STEM education in KS3 students and created a potential solution option through gamification. The key features of the product are its promotion not only of astronomy and science knowledge, but also of wider skills. 'Mission to Mars' is a game that develops it users into successful team players, improving their communication, problem solving and tactical thinking. Unlike many games it uses cooperation over competition and uses more than simple quiz mechanics (unlike many pedagogical games).

Unfortunately there was not an opportunity to test the product in schools with the target market, but this should be possible in Pioneer Schools within the next academic year. Despite this, the feedback from play testers was of an enjoyable and positive experience with 'Mission to Mars' and both Angela Darke, and contacts at Cardiff Commitment and in Cardiff University PHYSX were very enthusiastic about the game and the possibilities for improving STEM education in Wales.

The main lesson learned while completing this project is that there are always ways to expand on the work that has been done, which means there is always more potential for a project like this to grow. While time was managed well on this project with all the expected deliverables finished on time (following the project

Figure 52 Children enjoying a board game together (Hip2Save, 2018)

plan outlined in section 3.2), there is still potential for follow-up work. For example this game could benefit from regular updates and expansions or game variations based on real developments. The options for further work are discussed in section 8.1.

This project's focus was on the human factors associated with the product. The most important aspects of this are the interactions that the users have within the game, considering not just how they use the components but also how they interact amongst their team, working together not against each other. Peer learning and the combination of multiple learning styles leads to a more meaningful experience in the classroom. Human factors have also been considered when making choices such as the font (section 6.5.1), along with the component's sizes, rule book layout and game mechanics.

8.1 Future Work

8.1.1 Second Game in Series

As mentioned in the design brief, 'Mission to Mars' is intended to be the first in a series of three. All three games will be linked, each following on from the last, becoming progressively more involved. Each subsequent game will build on prior learning, meaning the more you remember the better you will do, which is a nice additional pedagogical aspect.

The follow up game to 'Mission to Mars' would be aimed at a Y8 target market and the purpose of this game would be to build a Mars base, suitable for human life, while terraforming the land around to allow for expansion. Science could be bought into the game through the need to grow plants, developing a food supply chain, mining the planet for resources and building the technology needed to survive Mars.

8.1.2 Third Game in Series

The final M2M educational game would be for the Y9 age group, focusing more on exploring the planet. The final game could take on a more geographical and geological educational theme, challenging players to navigate the Martian surface. It would also require players to use large amounts of maths, calculating distances travelled, durations of expeditions and quantity of supplies (e.g. oxygen) needed.

8.1.3 Open Source Content and Website

An initial website[15] has been setup by the author for the M2M brand, shown in construction in figure 53. The hope is that it will be a source of information and educational resources about astronomy, physics and Mars, for students and teachers.

It will also be a good place to host additional resources for the game. While initially the board game can be bought as a complete set, due to the environment of use and high chance of loss or breakage of parts, all elements need to be easily replaceable. The website provides a platform upon which all of the components can be detailed and re-purchased. Users will be able to download the rule book along with 3D print files of the pieces or order/print new cards with different or updated facts.

Currently the website is under construction, but further work would make it an excellent platform for educational users. It would be used to announce future game developments, for this game and any potential future games that are added to the series.

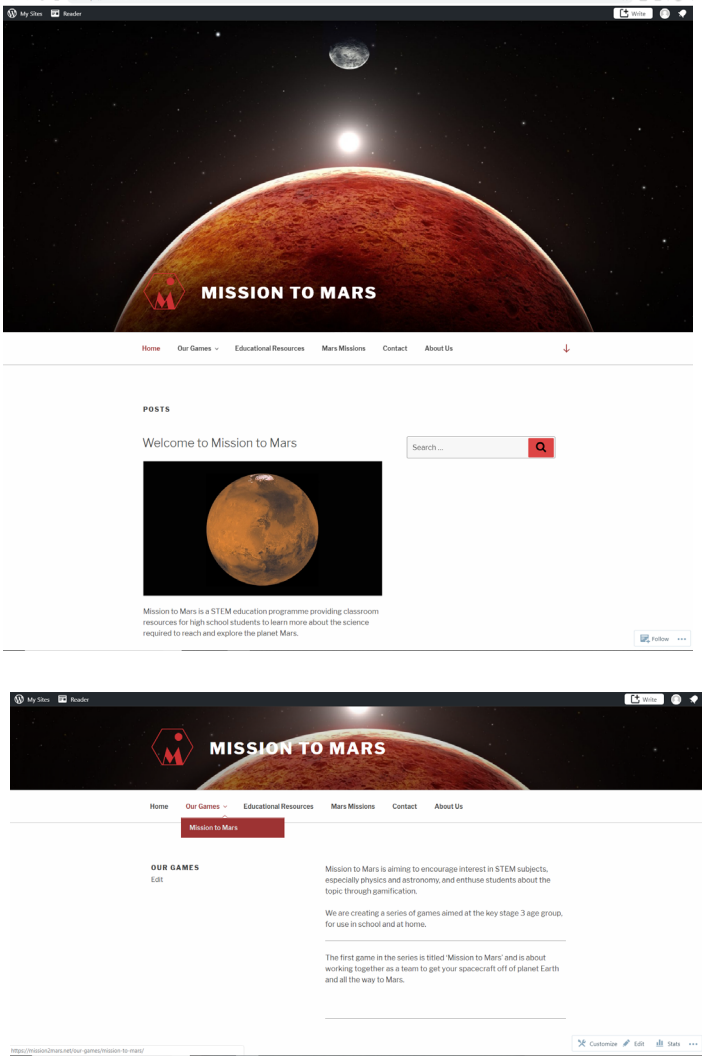


Figure 53 Screen shots of mission2mars.net

8.1.4 APPLICATION SUPPORT

While the game should not need technology or the Internet to play, the addition of app support could bring more to the experience, making it more meaningful and rewarding.

One early idea was the use of augmented reality. A smartphone, or tablet, camera could be focused above any of the cards in the deck and the screen would present a 3D model of that item along with additional information.

Users might also be able to unlock additional content if they scan a certain number of cards or a particular card.

Such an application may provide a way of tracking players achievements, while also having a built-in timer for the game and all the game instructions and rules for easy access.

However, the development of such an app could provide further complications for use in schools with access to technology being inconsistent. Although integrating smartphones into lessons is feasible, there are also advantages to providing a standalone boardgame version before providing potential enhancements.

8.1.5 WORK AND ACHIEVEMENTS BOOK

Although a student work book and reward scheme have been considered during this project (see section 6.6), it should be included as further work.

For the game to be optimised as an educational tool it needs an accompanying work book, containing both game play achievements and learning activities, where students can reflect upon their game experiences and record educational material.

Various activities need to be designed to join the achievements lists in the work book, which would encourage students to spend time reading the facts or replaying the game. The activities included could be simple, e.g. completing diagrams based on the game cards, or more complex encouraging the student to do further research, like writing a newspaper article about the benefits of space exploration. There are lots of options available and further research into the design of workbooks and educational activities would need to be done before the completion of this additional game component.

[15] mission2mars.net

LIST OF TABLES AND FIGURES:

Figure 1 Children enjoying a board game together (Hip2Save, 2018) 1
Figure 2 Education Industry Statistics (IBIS World, 2018) 1
Figure 3 Increase in large class sizes in the UK across a ten-year period (Rhodes, 2017) 4
Figure 4 Lesson map for Cardiff Council's new curriculum proposal (Darke, 2018) 5
Figure 5 'Destination Mars' board and player pieces (GeekBuddy Analysis, 2008) 11
Figure 6 'Destination Mars' game box, board and parts (GeekBuddy Analysis, 2008) 11
Figure 7 Destination Mars game cards (GeekBuddy Analysis, 2008) 11
Figure 8 'Dig Mars' game play layout (GeekBuddy Analysis, 2013) 12
Figure 9 A group playing 'Terraforming Mars' (GeekBuddy Analysis, 2016) 12
Figure 10 Box concept graphics for 'On Mars' (GeekBuddy Analysis, 2018) 12
Figure 11 Full layout of 'On Mars' showing all parts, pieces and cards (GeekBuddy Analysis, 2018) 12
Figure 12 'Gut Check' cards from initial concept to final edition (Coil, et al., 2017) 13
Figure 13 Responses to post-learning opinion survey (Trevino et al., 2016) 14
Figure 14 'Monopoly Deal' game play analysis infographics 15
Figure 15 'Escape the Hidden Temple' Game Play Analysis 16
Figure 16 Social and Emotional Skills: What to Expect at Different Ages (Morin, 2014a) 17
Figure 17 Math Skills: What to Expect at Different Age (Morin, 2014b) 17
Figure 18 KS3 students plans post compulsory education (Croll, 2003) 18
Figure 19 Initial Streamlined Gameplay Analysis (Roche, 2019a) 32
Figure 20 Overview of gameplay (Roche, 2019b) 33
Figure 21 Process for game set-up (Roche, 2019c) 33
Figure 22 Turn over mission tile sub-process (Roche, 2019d) 34
Figure 23 Movement sub-process (Roche, 2019e) 34
Figure 24 Final game play analysis 35
Figure 25 Mission to Mars project mood board (Roche, 2018) 39
Figure 26 Illuminae book cover and graphics (Kaufman & Kristoff, 2015) 40
Figure 27 Stage One Tile idea (Roche, 2018a) 41
Figure 28 Stage 2 Tile idea (Roche, 2018b) 41
Figure 29 Stage 3 Tile idea (Roche, 2018c) 41
Figure 30 Stage 4 Tile idea (Roche, 2018d) 41
Figure 31 Stage 5 Tile ideation (Roche, 2018e) 41
Figure 32 Game Board ideation (Roche, 2019f) 42
Figure 33 Century Gothic font 43
Figure 34 Development of the 'solar system fact card' design 43
Figure 35 Example 'item card' final design 43
Figure 36 Workbook front cover 44
Figure 37 Workbook student information page 44
Figure 38 Workbook introduction page and experience tracker 44
Figure 39 Example of gameplay achievements in workbook 44
Figure 40 Final Game Board Design (removal of card place signifiers and improvement of spacing) 45
Figure 41 Render of Mars game centre and Mars slices 45
Figure 42 3D print of the central Mars landing site section 46
Figure 43 Example game board set up 46
Figure 44 Completed Mars game board 46
Figure 45 The information/ID cards for the games six player characters 47
Figure 46 Game Mission tiles 48
Figure 47 Player piece render 48
Figure 48 Player pieces 48
Figure 49 Teacher lesson plan for Mission to Mars, based on lesson plans by Angela Darke

(shown in figure 3, section 2.2) 49
Figure 50 Game instruction manual 50
Figure 51 All player agency character components 54
Figure 52 Children enjoying a board game together (Hip2Save, 2018) 55
Figure 53 Screenshot of mission2mars.net 57

Table 1 Practical subjects and recommended class size (Education, 2018) 4
Table 2 Amazon data on a search for 'educational+games' (Unicorn Smasher, 2018) 10
Table 3 Amazon data on a search for 'space+games' (Unicorn Smasher, 2018) 10
Table 4 Young Peoples Attitudes to School by Age and Gender (Croll, 2003) 18
Table 5 Project timetable of tasks and hours to complete 23
Table 6 Project Critical pathway, showing order of work completion 24
Table 7 Project timeline 24
Table 8 Analysis of issues that may arise during game play 37

9.2 REFERENCES:

boardgamegeek, 2015. Celestia. [Online]
Available at: https://boardgamegeek.com/boardgame/175117/celestia
[Accessed 1 April 2019].

Cunnah, D., 2018. Education in Wales. [Presentation] Cardiff: Institute of Physics.

Darke, A., 2018. New Approach to science education [Interview] (29 October 2018).

Silverman, D., 2013. How to Learn Board Game Design and Development. [Online]
Available at: https://gamedevelopment.tutsplus.com/articles/how-to-learn-board-game-design-and-development--gamedev-11607
[Accessed 24 October 2018].

9.3 BIBLIOGRAPHY:

Answer the Public, 2018. Answer the Public: Edcational Games. [Online]
Available at: https://answerthepublic.com/reports/09eed4b7-4c2a-4f9f-ab70-118c5580590d
[Accessed 22 October 2018].

Anthony, M., 2013. Cognitive Development in 11-13-year olds. [Online]
Available at: https://www.scholastic.com/parents/family-life/creativity-and-critical-thinking/development-milestones/cognitive-development-11-13-year-olds.html
[Accessed 24 October 2018].

Azimita, M., 1988. Peer Interation and Problem Solving: When are twoheads better than one?. Child Development, Issue 59, pp. 87-96.

BBC News, 2014. How is the national curriculum changing?. [Online]
Available at: https://www.bbc.co.uk/news/education-28989714
[Accessed 19 October 2018].

boardgamegeek, 2015. Celestia. [Online]
Available at: https://boardgamegeek.com/boardgame/175117/celestia
[Accessed 1 April 2019].

Boardgames Maker, 2018. Custom Game Boards. [Online]
Available at: https://www.boardgamesmaker.com/customized/custom-game-boards.html
[Accessed 22 November 2018].

Bochennek, K., 2007. More than mere Games: a review of card and board games for medical education. Medical Teacher, Issue 29, pp. 941-948.

British Educational Suppliers Association, 2018. Key UK Educational Statistics. [Online]
Available at: https://www.besa.org.uk/key-uk-education-statistics/
[Accessed 19 October 2018].

BSI Group, 2014. Playing safe: A Consumer's guide to the British Standard for Toy Safety. [Online]
Available at: https://www.bsigroup.com/LocalFiles/en-GB/consumer-guides/resources/BSI-Consumer-Brochure-Playing-Safe-UK-EN.pdf
[Accessed 18 Noveber 2018].

BSI Group, 2016. BS EN 71-1 AMD2. Safety of toys.. [Online]
Available at: https://bsol-bsigroup-com.ezproxy.brunel.ac.uk/PdfViewer/Viewer?pid=000000000030318994
[Accessed 18 November 2018].

Card, O. S., 1985. Ender's Game. 1 ed. New York: Tor.

Card, O. S., 2014. Creative education--how to keep the spark alive in children and adults | Orson Scott Card | TEDxUSU. s.l.: TEDx Talks.

Cartwright, M., 2014. Mars. [Online]
Available at: https://www.ancient.eu/Mars/
[Accessed 22 November 2018].

Coil, D. A., Ettinger, C. L. & Elsen, J. A., 2017. Gut Check: The Evolution of an Educational Board Game. 28 April.15(4).

Collins Dictionary, 2018. Definition of 'physical'. [Online]
Available at: https://www.collinsdictionary.com/dictionary/english/physical
[Accessed 1 November 2018].

Cool Cosmos, 2013. Why is Mars reddish?. [Online]
Available at: http://coolcosmos.ipac.caltech.edu/ask/69-Why-is-Mars-reddish-
[Accessed 22 November 2018].

Crehan, L., 2016. Cleverlands: The Secrets Behind the Success of the World's Education Superpowers. London: Unbound.

Croll, P., 2003. Young People's Trajectories into Post-compulsory Education and Training: a preliminary analysis of data from the British Household Panel Survey, s.l.: Annual Conference of the British Educational Research.

Cunnah, D., 2018. Education in Wales. Cardiff: Institute of Physics.

Darke, A., 2018. Mars Educational Materials Development Grant Scheme, Cardiff: UK Space Agency.

Darke, A., 2018. Mars One. Cardiff: s.n.

Darke, A., 2018. New Approach to science education [Interview] (29 October 2018).

Department for Education, n.d. Class Size and Education in England, s.l.: s.n.

Department of Education, 2018. Pupils and Classes. [Online]
Available at: https://www.education-ni.gov.uk/articles/pupils-and-classes
[Accessed 16 October 2018].

Department of Health, 2014. DEVELOPING WELL – 11-19 YEARS, s.l.: s.n.
dictionary.com, 2012. Video game. [Online]
Available at: https://www.dictionary.com/browse/video-game
[Accessed 1 November 2018].

Donaldson, G., 2015. Successful Futures - Independant Review of Curriculum and Assessment Arrangements in Wales, s.l.: OGL.

Eckert, G. U., 2004. Learning from Panel Boards: T-lymphocyte and B-lymphocyte self-tolerance game. Medical Teaching, 26(6), pp. 521-524.

Education Wales, 2017. Education in Wales: Our National Mission, Cardiff: OGL.
GeekBuddy Analysis, 2008. Destination Mars. [Online]
Available at: https://boardgamegeek.com/boardgame/6434/destination-mars
[Accessed 31 October 2018].

GeekBuddy Analysis, 2013. Dig Mars. [Online]
Available at: https://boardgamegeek.com/boardgame/147889/dig-mars
[Accessed 31 October 2018].

GeekBuddy Analysis, 2016. Terraforming Mars. [Online]
Available at: https://boardgamegeek.com/boardgame/167791/terraforming-mars
[Accessed 31 October 2018].

GeekBuddy Analysis, 2018. On Mars. [Online]
Available at: https://boardgamegeek.com/boardgame/184267/mars
[Accessed 31 October 2018].

Gershen, J., 1974. Role-playing as an Educational Technique in Denistry. Journal of Dental Education, Volume 38, pp. 451-455.

Gibbons, M. & Hopkins, D., 1980. How Experiental is your Experience-based program?. Journal of Experiental Education, 3(1), pp. 32-37.

Gov.uk, 2013. Devolution settlement: Wales. [Online]
Available at: https://www.gov.uk/guidance/devolution-settlement-wales
[Accessed 30 October 2018].

Henry, H., 1997. Gaming: a teaching strategy to enhance adult learning. Journal of Continuing Education in Nursing, 28(5), pp. 231-234.

Hip2Save, 2018. Double Ditto. [Online]
Available at: https://hip2save.com/2018/11/29/amazon-double-ditto-family-board-game-only-11-97-shipped-awesome-reviews/
[Accessed 14 April 2019].

Howe, C. et al., 2007. Group Work in Elementary Science. Learning and Instruction, September, Issue 17, pp. 549-563.

IBIS World, 2018. General Secondary Education - UK Market Research Report. [Online]
Available at: https://www.ibisworld.co.uk/industry-trends/market-research-reports/education/general-secondary-education.html
[Accessed 19 October 2018].

Invest in Cardiff, 2018. What is the Cardiff Commitment?. [Online]
Available at: http://www.investincardiff.com/main/the-cardiff-commitment/
[Accessed 19 October 2018].

Kaufman, A. & Kristoff, J., 2015. Illuminae (The Illuminae Files). [Online]
Available at: https://www.amazon.com/Illuminae-Files-Amie-Kaufman/dp/0553499114
[Accessed 16 February 2019].

Kelly, A., 1974. Teaching Mixed Abilty Class. Suffolk: Harper & Row Ltd..
Merriam Webster, 2018. video game. [Online]
Available at: https://www.merriam-webster.com/dictionary/video%20game
[Accessed 1 November 2018].

Morin, A., 2014a. Social and Emotional Skills: What to Expect at Different Ages. [Online]
Available at: Social and Emotional Skills: What to Expect at Different Ages
[Accessed 24 October 2018].

Morin, A., 2014b. Math Skills: What to Expect at Different Age. [Online]
Available at: https://www.understood.org/en/learning-attention-issues/signs-symptoms/age-by-age-learning-skills/math-skills-what-to-expect-at-different-ages
[Accessed 24 October 2018].

Neame, R. & Powers, S., 1981. Towards Independant Learning: curricular design for assissting students to

learn how to learn. Journal of Medical Education, Volume 56, pp. 886-893.

O'Neill, M., 2017. Curriculum reform in Wales. [Online]
Available at: https://www.atl.org.uk/curriculum-reform-wales
[Accessed 16 October 2018].

Pandey, A., 2015. Top 6 Benefits of Gamification eLearning. [Online]
Available at: https://elearningindustry.com/top-6-benefits-of-gamification-in-elearning
[Accessed 8 November 2018].

Prime Office Space, 2014. The Top Ten Industries in the UK. [Online]
Available at: https://primeofficespace.co.uk/latest/top-ten-industries-in-uk/
[Accessed 19 October 2018].

Ramani, G. B., Siegler, R. S. & Hitti, A., 2012. Taking it to the Classroom: Number Board Games as a Small Group Learning Activity. Journal of Educational Psychology, 104(3), pp. 661-672.

Reiff, J. C., 1992. Learning Styles. What Research Says to the Teacher, s.l.: National Education Association, Washington, DC..

Reyna, V. F., 1996. Conceptions of Memory Development, with implications for reasoning and decision making. Annals of Child Development, Issue 12, pp. 87-118.

Rhodes, D., 2017. Number of children taught in large classes trebles. [Online]
Available at: https://www.bbc.co.uk/news/uk-england-38506305
[Accessed 16 October 2018].

Roche, C., 2018a. Rocket Building. [Art] (Brunel University London).

Roche, C., 2018b. Take-Off. [Art] (Brunel University London).

Roche, C., 2018c. The Journey. [Art] (Brunel University London).

Roche, C., 2018d. Orbit. [Art] (Brunel University London).

Roche, C., 2018e. Land. [Art] (Brunel university London).

Roche, C., 2018. Mission to Mars moodboard. [Art] (Brunel University London).

Roche, C., 2018. Yellow to Red gradient. [Art] (Brunel University London).

Roche, C., 2019a. Initial Gameplay Analysis FLowchart. [Art] (Brunel University London).

Roche, C., 2019b. Overview Gameplay Analysis. [Art] (Brunel Unversity London).

Roche, C., 2019c. Process for game setup. [Art] (Brunel University London).

Roche, C., 2019d. Mission Hex process. [Art] (Brunel University London).

Roche, C., 2019e. Move game process. [Art] (Brunel University London).

Roche, C., 2019f. Initial Game Board Idea. [Art] (Brunel University London).

Roche, C., 2019g. Final game play analysis flow chart. [Art] (Brunel University London).

Roche, C., 2019h. M2M game board. [Art] (Brunel University London).

Roche, C., 2019i. SolidWorks render of Mars landing site and pieces. [Art] (Brunel University London).

Roche, C., 2019j. Photo of 3D printed Mars landing site. [Art] (Brunel University London).

Roche, C., 2019k. Mission to Mars game photos. [Art] (Brunel University London).

Roche, C., 2019l. Player character cards. [Art] (Brunel University London).

Roche, C., 2019. Mission to Mars logo. [Art] (Brunel University London).

Roche, C., 2019m. Solidworks render of player piece. [Art] (Brunel University London).

Roche, C., 2019n. Lesson plan. [Art] (Brunel University London).

Roche, C., 2019o. Photos of M2M instruction manual. [Art] (Brunel University London).

Roche, C., 2019p. Player components. [Art] (Brunel University London).

Sears, J., 2017. Safety Testing your Board Game. [Online]
Available at: https://pixygamesuk.blogspot.com/2017/06/safety-testing-your-board-game-special.html
[Accessed 18 November 2018].

Seeber, E., 2017. Ditching the sets: why we're teaching mixed ability lessons for science. [Online]
Available at: https://www.theguardian.com/teacher-network/teacher-blog/2017/nov/22/ditching-the-sets-why-were-teaching-mixed-ability-lessons-for-science
[Accessed 27 November 2018].

Sellgren, K., 2017. Should young children be grouped by ability?. [Online]
Available at: https://www.bbc.co.uk/news/education-42154013
[Accessed 27 November 2018].

Silverman, D., 2013. How to Learn Board Game Design and Development. [Online]
Available at: https://gamedevelopment.tutsplus.com/articles/how-to-learn-board-game-design-and-development--gamedev-11607
[Accessed 24 October 2018].

Space Facts, 2018. Space Facts: Mars. [Online]
Available at: https://space-facts.com/mars/
[Accessed 22 November 2018].

Spiele Material, 2015. Plastic Bases. [Online]
Available at: https://www.spielematerial.de/en/game-components/game-pieces/plastic-bases/plastic-bases-flexible.html
[Accessed 22 November 2018].

Squire, K. & Jenkins, H., 2003. Harnessing the Power of Games in EDucation. Insight, Volume 3, pp. 5-33.
Steimen, R. A. & Blastos, M. T., 2002. A Trading-Card game teaching about Host Defense. Journal of Medical Education, 36(12), pp. 1201-1208.

Stemple, A., 2016. Before You Buy a Deck of Playing Cards. [Online]
Available at: https://www.thoughtco.com/buying-a-deck-of-playing-cards-2728282
[Accessed 22 November 2018].

Strategist, H., 2018. The Types of Board Games Everyone Should Know About. [Online]
Available at: https://nonstoptabletop.com/blog/2017/7/30/the-10-types-of-board-games-everyone-should-know-about
[Accessed 17 October 2018].

Tabletop Companion, 2018. A GAme Changer. [Online]
Available at: https://www.tabletop-companion.com/
[Accessed 22 November 2018].

The Royal Society, 2017. Graham Donaldson - Biography. [Online]
Available at: https://royalsociety.org/people/graham-donaldson-13113/
[Accessed 19 October 2018].

Trevino, R. et al., 2016. The Effectiveness of an Educational Game for Teaching Optometry Students Basic and Applied Science. PLOS One, 11(5).

Unicorn Smasher, 2018. Amazon Tracker. [Online]
Available at: https://www.unicornsmasher.com/
[Accessed 22 October 2018].

Wasik, B. A., 2008. When Fewer is More: Small groups in early childhood classrooms. Early Childhood Education Journal, Volume 35, pp. 515-521.

Wightwick, A., 2018. This is how Cardiff's 18 secondary schools compare in 2018. [Online]
Available at: https://www.walesonline.co.uk/news/education/how-cardiffs-18-secondary-schools-15176675
[Accessed 19 October 2018].

Figure 2.1: Year 8, Lesson Two Mars datasheet

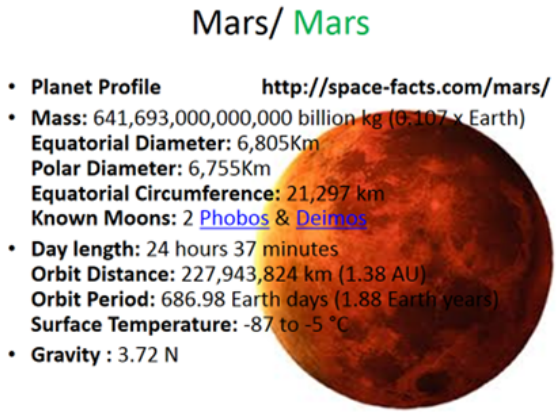
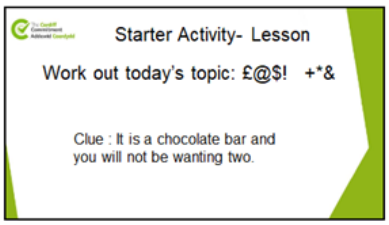
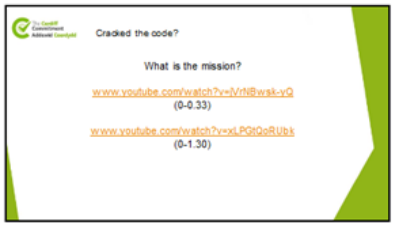
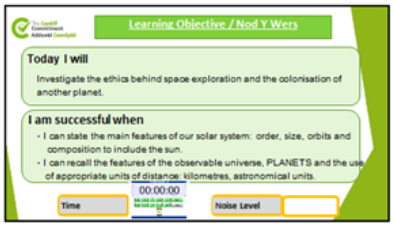


Figure 2.2: Draft of Year 8, Lesson Two PowerPoint







Section 2.3: Angela Darke relevant interview quotes

"My main interest is in the curriculum and I feel that this is an incredible opportunity to inspire the next generation with cutting edge Science that is relevant and helps to attract the more able students."

"I feel a Mars-themed approach will provide excellent opportunities for cross-curricular and inter-disciplinary learning in Wales."

"Much of the initial groundwork on many of the lessons has already been done."

"I want to finesse the materials to match the final Donaldson recommendations, ensure suitable matches with the UKSA and ESERO-UK requirements and targets, and develop the overall themed of the resources."

"As a result of Donaldson, topics will no longer be taught in distinct packages and will not follow the more traditional approach i.e Cells, Forces, the Periodic Table etc. will be no longer taught as topics on their own. The Biology, Chemistry and Physics content of KS3 will be covered within themes. There will be 8 themes which will take two years to complete, and under our plans "Mars" will be the first theme."

"Mars has been selected as it is a very interesting interdisciplinary theme and is very topical and aspirational. At present the topics to be included would be the Early Atmosphere, modern air, Martian air. Breathing and respiration, Food chains, Food webs, Seven characteristics of living things, Creating soil, Cells, Photosynthesis, Gas tests, Water, Food types, balanced diet, Eating disorders, Recycling, Carbon Cycle, Nitrogen Cycle, Smart Materials, Gravity and Newton's laws. The theme will also have a discussion and will have an investigation based on the best insulating material (as an investigation into space suits)."

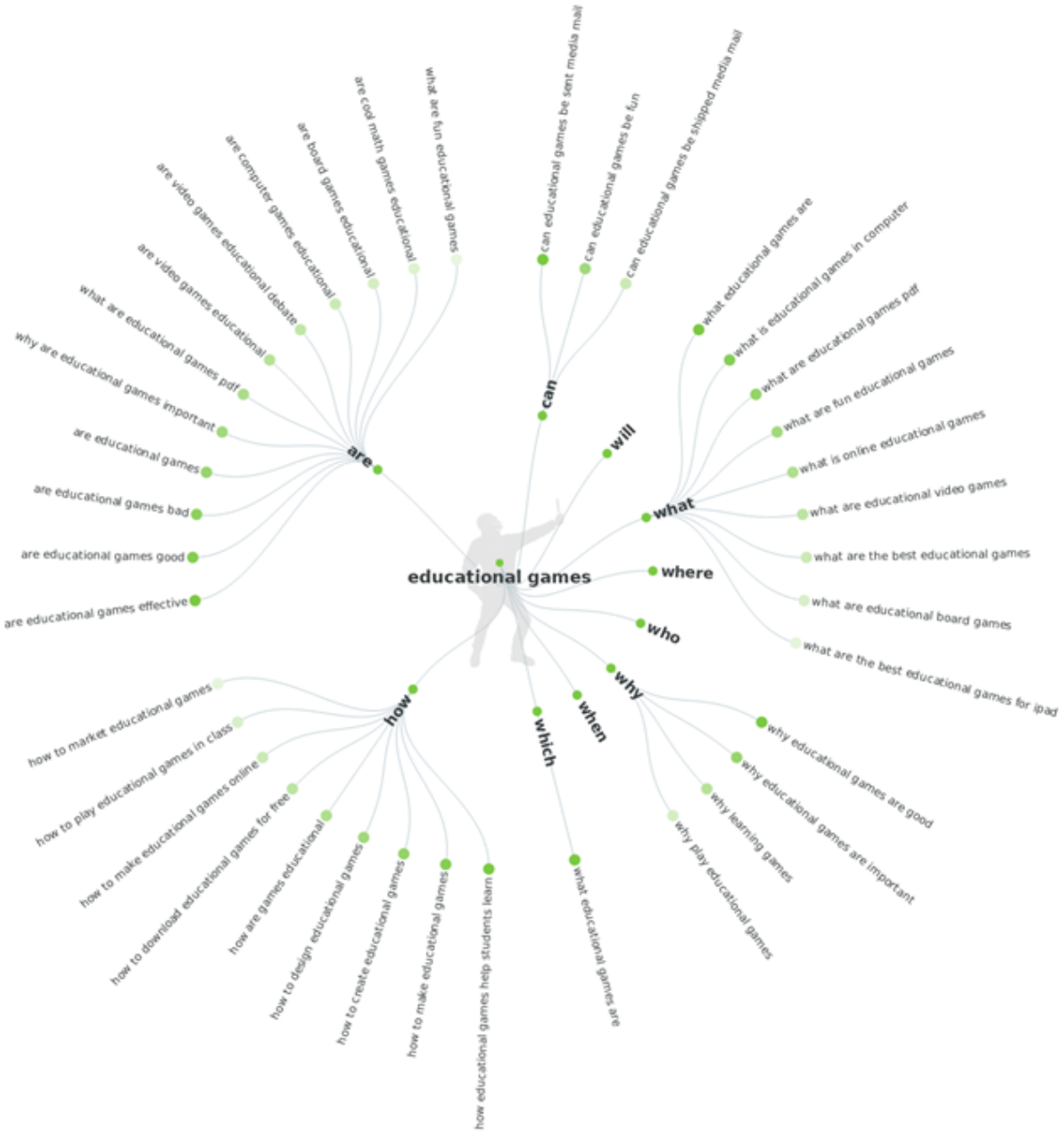
"It is also planned that I will be involved in the concept design of two "challenge rooms" based in two of the School Buildings New Buildings being built in Cardiff over the next couple of years (as part 385 million pound building programme)."

"The intention is for the resources to be made available asap - they would be trialled initially at the new Cardiff West Community High School, and with some of the Donaldson Pioneer Schools, before being rolled out across all Cardiff secondary schools (20 schools, ~3,000 students) in 2019."

"Once the resources have been properly trialled and evaluated, they will be made available to all 211 secondary schools across Wales for the 2020 launch of the new curriculum (and hopefully reaching around half of the ~31,000 KS3 students in Wales each year)."

"I want resources to be designed with a "Mission to Mars" look and feel, to enhance the attractiveness to pupils in particular."

Figure 2.4: Research into the publics searches for educational games (Answer the Public, 2018)



FINAL YEAR MAJOR DESIGN PROJECT
TUTORIAL RECORD

This form should be completed after discussion with your supervising tutor. Compile these forms into a record file and use them to reflect on progress, timings and key tasks undertaken during the project.

Indicative template for good professional practice and meeting record keeping

Meeting with:	Date:
Dr Olinkha Gustafson-Pearce	14/11/2018
Purpose of meeting:	
Weekly supervisor meeting	
Items produced for discussion:	
Game segmentation research	
Points arising:	
1. Product design specifications 2. Look into the National Geographic Mars programme 3. The use of mnemonics and storytelling, about the mythology of Mars and the solar system 4. Game play analysis, considering human factors aspects of children playing games	
Actions agreed:	**Completion by (date)**
1. Begin the product specification, looking at examples form previous interim reports 2. Complete a game play analysis on up to 4 games 3. Use infographics to display game play analysis	21/11/2018
	Supervisor's signature
	OGP

FINAL YEAR MAJOR DESIGN PROJECT

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Indicative template for good professional practice and meeting record keeping

Meeting with:	Date:
Dr Olinkha Gustafson-Pearce	30/01/2019
Purpose of meeting:	
Weekly supervisor meeting	
Items produced for discussion:	
Overview gameplay analysis flowchart	
Points arising:	
1. Flowchart/Gameplay analysis needs to consider all aspects of the game 2. If not everyone can understand the gameplay analysis it isn't comprehensive enough, what are the subroutines involved 3. What is the teacher/supervisor doing when students are playing the game?	
Actions agreed:	**Completion by (date)**
1. Keep plugging work into the dissertation document (e.g. quick notes, write-ups, images etc.) 2. More comprehensive flowchart of gameplay (extend!) 3. What are the learning outcomes of the game and at each stage	13/02/19
	Supervisor's signature
	OGP

Figures 3.1-3.14 Supervisor meeting minutes

FINAL YEAR MAJOR DESIGN PROJECT
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Indicative template for good professional practice and meeting record keeping

Meeting with:	Date:
Dr Olinkha Gustafson-Pearce	~~24/11/2018~~ 23/01/19
Purpose of meeting: Weekly supervisor meeting	
Items produced for discussion: Game board design	
Points arising: 1. Discussion of what a gameplay analysis should be/look like, it's more like a flowchart not a set of instructions and design 2. The science that will be included in the game is decided on and the game purpose can now be focused more 3. Looking at previous timescales/timelines and readjusting them now that the understanding of the project has increased	
Actions agreed: 1. Make a flowchart of gameplay (how it plays, what happens when x, etc.) 2. Rethink timeline/timetable 3. Try and be more focused with the project purpose/deliverables	Completion by (date) 06/02/19 Supervisor's signature OGP

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Indicative template for good professional practice and meeting record keeping

Meeting with:	Date:
Dr Olinkha Gustafson-Pearce	~~18/01/2019~~ ~~16/01/19~~ 16/01/19
Purpose of meeting: Weekly supervisor meeting	
Items produced for discussion: Feedback from interim submission and viva presentation	
Points arising: 1. Not enough detail considering gameplay and game instructions 2. Spelling mistakes in interim report, need to improve proof-reading 3. Discussion of other module work and workloads 4. Consideration of cross-medium products	
Actions agreed: 1. Look at games and see how easy they are to follow 2. Think about a 'future work' section to include at the end of the dissertation 3. Have something more than just slides for presentations e.g. models, prototypes etc.	Completion by (date) 23/01/19 Supervisor's signature OGP

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TUTORIAL RECORD

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Indicative template for good professional practice and meeting record keeping

Meeting with:	Date:
Dr Olinkha Gustafson-Pearce	07/12/2018
Purpose of meeting:	
Weekly supervisor meeting	
Items produced for discussion:	
Interim and Viva prep.	
Points arising:	
1. Term 1 should have been focused on research, the break should focus on ideation and then term 2 should be used for making and developing 2. Develop ideas that can be included in the interim report/viva 3. Be clear on why you have chosen the route you have chosen, justify all choices 4. Think about what you re going to do next with the project, include this in the report conclusion and viva	
Actions agreed: 1. Finish writing the interim report 2. Create a viva with clear and professional slides 3. Think about ecological issues and the life-cycle of materials that may be used	Completion by (date) 10/12/2018
	Supervisor's signature 

FINAL YEAR MAJOR DESIGN PROJECT
TUTORIAL RECORD

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Indicative template for good professional practice and meeting record keeping

Meeting with:	Date:
Dr Olinkha Gustafson-Pearce	7/11/2018
Purpose of meeting:	
Weekly supervisor meeting	
Items produced for discussion:	
Background research findings	
Points arising:	
1. Viva presentation dates 2. Industry Review Evening boards	
Actions agreed: 1. Define what the students will need to know 2. Break down the game into clear sections 3. Consider how the students will feel like they have achieved something, and ways of rewarding them after each stage/section 4. Decide whether competitive and cooperative games are a driving factor or a turn-off	Completion by (date) 14/10/2018
	Supervisor's signature 

FINAL YEAR MAJOR DESIGN PROJECT
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Indicative template for good professional practice and meeting record keeping

Meeting with:	Date:
Dr Olinkha Gustafson-Pearce	31/10/2018
Purpose of meeting: Weekly supervisor meeting	
Items produced for discussion: Background research findings	
Points arising: 1. Use of consent forms 2. Industry Review Evening boards 3. How to reference previously submitted work 4. Writing of product design briefs	
Actions agreed: 1. Continue background research with experts and literature reviews 1. Define what topic the game will cover 2. Develop an initial design brief	Completion by (date) 7/11/2018
	Supervisor's signature OGP

FINAL YEAR MAJOR DESIGN PROJECT
TUTORIAL RECORD

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Meeting with:	Date:
Dr. Olinkha Gustafson-Pearce	24/10/2018
Purpose of meeting: Weekly update meeting/Check-in	
Items produced for discussion: Dissertation contents page, project timetable, project timeline	
Points arising: 1. The contents page lacking the full detail required at this stage, include name in the header/footer of documents being sent to Olinkha 2. The timetable and critical pathway are useful but now need to be put into a time-line (e.g. month by month or weekly tasks), also they are functional but might work better with nicer graphics) 3. When writing the dissertation never say anything definitive, reference back to your own work (e.g. product specification) and write in third person (no I/me) 4. The formatting and testing of questionnaires 5. Looking at alternative game styles (not table-top) could be virtual or physical	
Actions agreed: 1. Create a time-line of the project 2. Expand on the contents page, break items down more resulting in 8-10 main sections 3. Research alternative game styles	Completion by (date) 31/10/2018
	Supervisor's signature OGP

FINAL YEAR MAJOR DESIGN PROJECT
TUTORIAL RECORD

This form should be completed after discussion with your supervising tutor. Compile these forms into a record file and use them to reflect on progress, timings and key tasks undertaken during the project.

Meeting with:	Date:
Dr. Olinkha Gustafson-Pearce	17/10/2018
Purpose of meeting: Discuss background research progress and design brief ideas	
Items produced for discussion: Interesting points of background research	
Points arising: 1. Discussion of Ethics approval issues and the ethics approval form 2. What should be included and excluded from the interim report and previous examples of Interim reports that are available on Blackboard 3. Contents pages of three previous design students' dissertations, to help with deciding the layout of report 4. Importance of assigning how long tasks will take in a timeline/table 5. The use of humour and rewards in education and games, how this might help engage/incentivise students to learn	
Actions agreed 1. Complete Contents page and send to Olinkha 2. Create a table of tasks and how many hours they will take to complete	**Completion by (date)** 24/10/2018 **Supervisor's signature** GP

FINAL YEAR MAJOR DESIGN PROJECT
TUTORIAL RECORD

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Indicative template for good professional practice and meeting record keeping

Meeting with:	Date:
Dr Olinkha Gustafson-Pearce	10/10/2018
Purpose of meeting: Initial meeting to explain project concept	
Items produced for discussion: Initial concept and statement of intent	
Points arising: 1. Research areas 2. Developing a timeline 3. Dissertation contents page 4. Referencing and ethics	
Actions agreed: 1. Develop a comprehensive timeline, considering the 'critical path' of the project 2. Make a contents page for the dissertation with titles for sections (e.g. the types of research) 3. Research into the STEM curriculum in Wales	**Completion by (date)** 22/10/2018 **Supervisor's signature** GP

FINAL YEAR MAJOR DESIGN PROJECT
TUTORIAL RECORD

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Indicative template for good professional practice and meeting record keeping

Meeting with:	Date:
Dr Olinkha Gustafson-Pearce	06/03/19
Purpose of meeting:	
Weekly supervisor meeting	
Items produced for discussion:	
Play testing results	
Points arising:	
1. Discussion of playtesting with two separate groups, and the need to show where there has been iteration and changes to the game 2. Highlighting human factors elements 3. How would playtesting be affected if done by those in the target market (e.g. children knocking things everywhere)	
Actions agreed:	**Completion by (date)**
1. Keep plugging work into the dissertation document (e.g. quick notes, write-ups, images etc.) 2. Check the serious games website 3. Think about all the human interaction factors and what can be developed to help/improve these	20/03/19
4. Consider a comprehensive set of rules/instructions developed specifically for the teacher/adult	**Supervisor's signature** OGP

FINAL YEAR MAJOR DESIGN PROJECT
TUTORIAL RECORD

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Indicative template for good professional practice and meeting record keeping

Meeting with:	Date:
Dr Olinkha Gustafson-Pearce	28/11/18
Purpose of meeting:	
Weekly supervisor meeting	
Items produced for discussion:	
Points arising:	
1. The need to create sketches and ideation before the viva/interim report deadline 2. What can the child have that is theirs, e.g. something to take home with them 3. Look at alternative routes to boardgames 4. Do more game play analysis	
Actions agreed:	**Completion by (date)**
1. Create an overview of alternative options and then explain why the chosen one has been selected (with good reason) 2. Really try and flesh out some game mechanics 3. Put together a draft viva	05/12/18
4. Complete the first draft of interim report	**Supervisor's signature** OGP

FINAL YEAR MAJOR DESIGN PROJECT
TUTORIAL RECORD

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Indicative template for good professional practice and meeting record keeping

Meeting with:	Date:
Dr Olinkha Gustafson-Pearce	13/02/19
Purpose of meeting:	
Weekly supervisor meeting	
Items produced for discussion:	
Game play analysis flowchart	
Points arising:	
1. More complex flowchart is needed, focusing on what could go wrong throughout the game or at stages (e.g. players leaving, pausing clock etc.) 2. Expand and define how players are interacting with each other 3. It is time to start finalising what will actually be made (the final concept)	
Actions agreed:	**Completion by (date)**
1. Define what the final submission will be (deliverables) 2. Really try and flesh out game mechanics 3. Look at the human interaction 4. Start planning a playtesting session	27/02/19
	Supervisor's signature CBP

FINAL YEAR MAJOR DESIGN PROJECT
TUTORIAL RECORD

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Indicative template for good professional practice and meeting record keeping

Meeting with:	Date:
Dr Olinkha Gustafson-Pearce	13/02/19
Purpose of meeting:	
Weekly supervisor meeting	
Items produced for discussion:	
Rule/Instructions booklet	
Points arising:	
1. Check carefully for spelling errors 2. Avoid centred font that can be hard to follow/track, and also keep information in a constant spacing to be found (game length times) 3. Be careful with using a red on black 4. Can any parts be personalised by the players?	
Actions agreed:	**Completion by (date)**
1. Justify the font choice made (e.g. easy to read 'a') 2. Do games testing 3. Carry on	06/03/19
	Supervisor's signature CBP

4.1 BRANDING OUTLINE

The game will be a part of the larger 'Mission to Mars' (M2M) brand, which is a part of the 'Universe Lab'[16], along with 'Down 2 Earth'[17] (D2E) and other science-based outreach programmes. The author created new branding for D2E during a placement year at 'National Museums Wales'[18] , and will now be required to create a logo and graphic templates for both 'Mission to Mars' and 'Universe Lab'. The 'Universe Lab' branding can be seen in the appendix (figures 4.1 and 4.2).

Figure 4.1 UniverseLab logo ideation

Figure 4.2 UniverseLab final logo

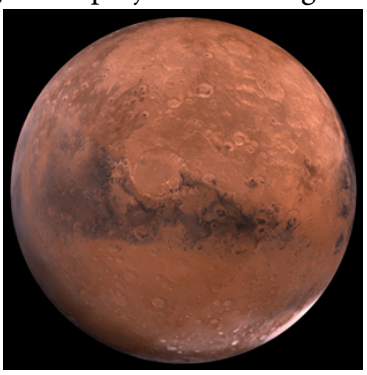
[16] Universe Lab covers all areas of astronomy (such as planets, asteroids and galaxies) along with using virtual and augmented reality.

[17] Down2Earth is run by the Universe Lab in partnership with the National Museum of Wales, supported by funding from the Science Technology Facilities Council (STFC). The project encompasses a variety of resources for students and teachers, enabling them to learn more about the science of asteroids and comets (including their detection, orbits, deflection, effects of impacts, mass extinctions and the properties of meteorites).

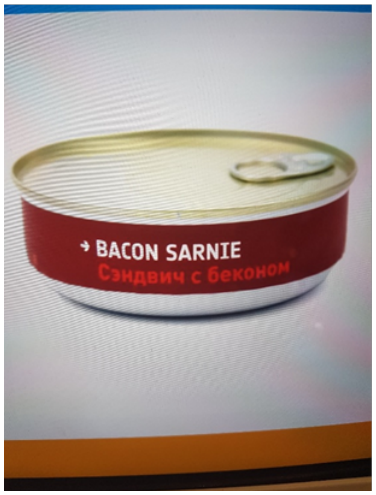
[18] A Welsh Government sponsored body that comprises seven museums in Wales: National Museum (Cardiff), St Fagans National Museum of History (Cardiff), Big Pit National Coal Museum (Blaenavon), National Wool Museum (Dre-fach Felindre near Llandysul), National Slate Museum (Llanberis), National Roman Legionary Museum (Caerleon), National Waterfront Museum (Swansea).

4.2 M2M BRANDING RESEARCH

To create the branding for this project it was important to look into what is traditionally associated with space and Mars in particular. Mars is named after the Roman God of War (Cartwright, 2014) and is known as the red planet, for its distinctive colouring shown in figure 4.3. The surface of Mars is an orange-red colour due to rust, or iron oxide particles (Cool Cosmos, 2013). This association with Mars and the colour red is an important element to consider including in the projects branding.



In order to get a better idea of what shapes, symbols and icons are space themed a research trip to the National Space Centre[19] and Challenger Centre[20] in Leicester was conducted. Some images from this trip can be seen in figures 4.4 to 4.29

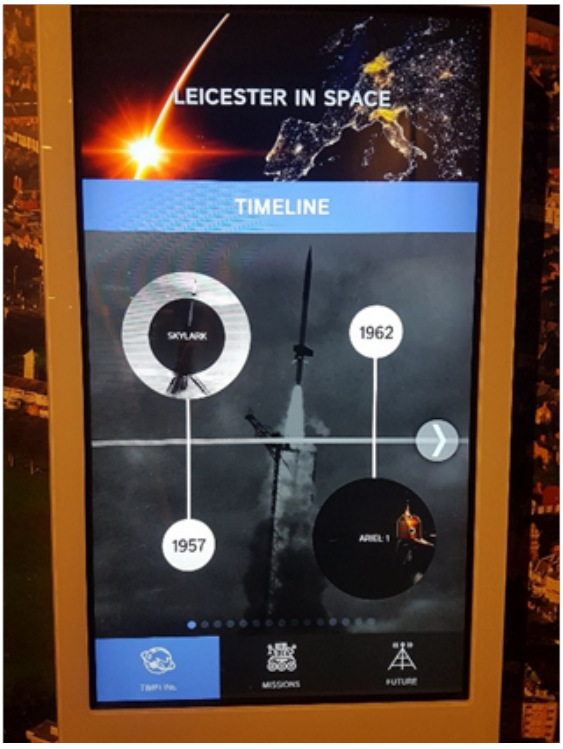


[19] The Space Centre is a museum where you can discover six galleries, including the iconic Rocket Tower and the UK's largest domed planetarium, crammed full of space suits, rockets, satellites and meteorites.
[20] Center Missions are STEM experiences designed for middle school students and available at Challenger Learning Centers around the globe. The space-themed simulation-based experiences are led by trained Flight Directors and take place in a fully immersive Space Station and Mission Control.

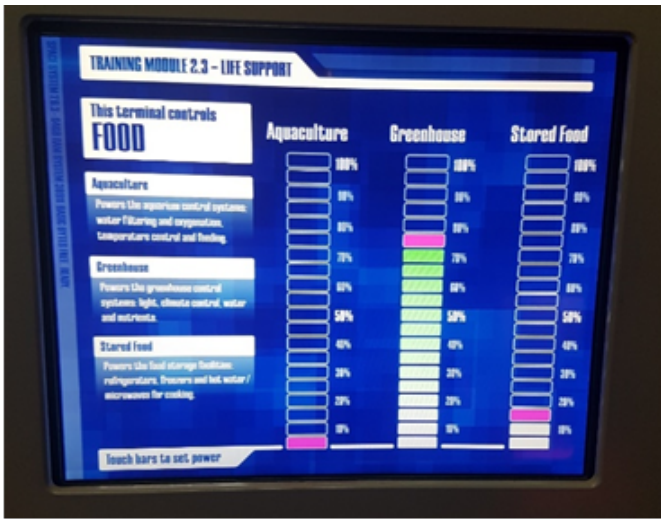

STARS
PLANETS
CONSTELLATIONS
CLEAR
DEEP SKY
MULTI-LEVELLED
INFORMATION DISPLAY


TRANQUILLITY
BASE


Welcome to the
WeatherPOD
ENTER


LEICESTER IN SPACE
TIMELINE
SKYLARK
1962
1957
ARIEL 1
MISSIONS
FUTURE

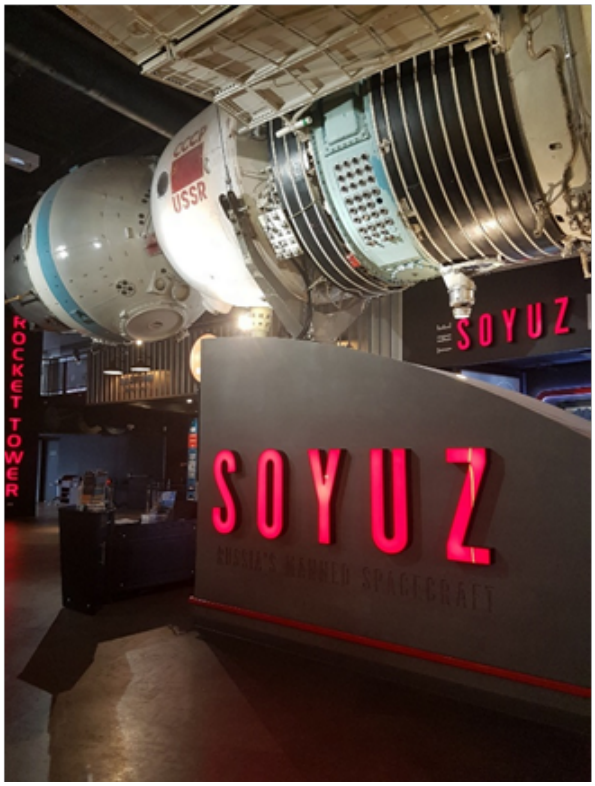

TRAINING MODULE 2.2 – LIFE SUPPORT
STATION ACTIVATED

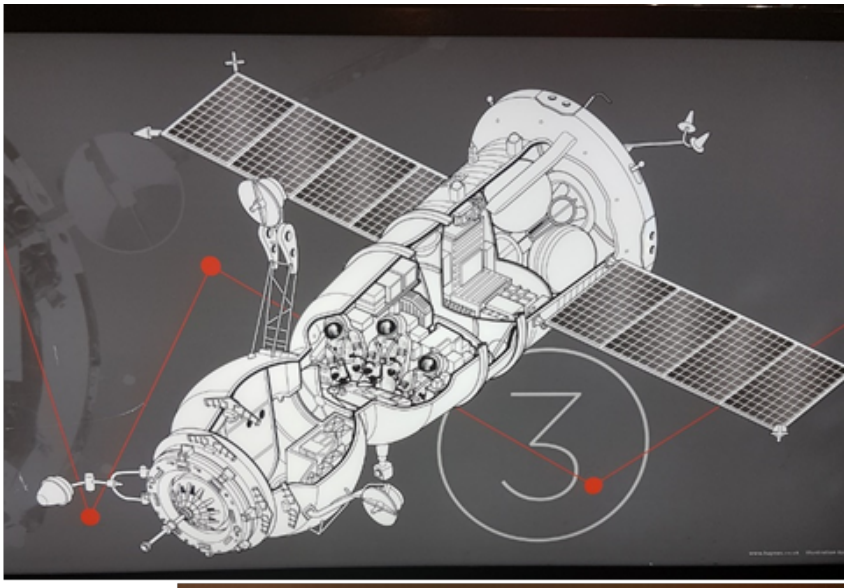

TRAINING MODULE 2.3 – LIFE SUPPORT
This terminal controls
FOOD
Aquaculture
Greenhouse
Stored Food
Touch bars to set power

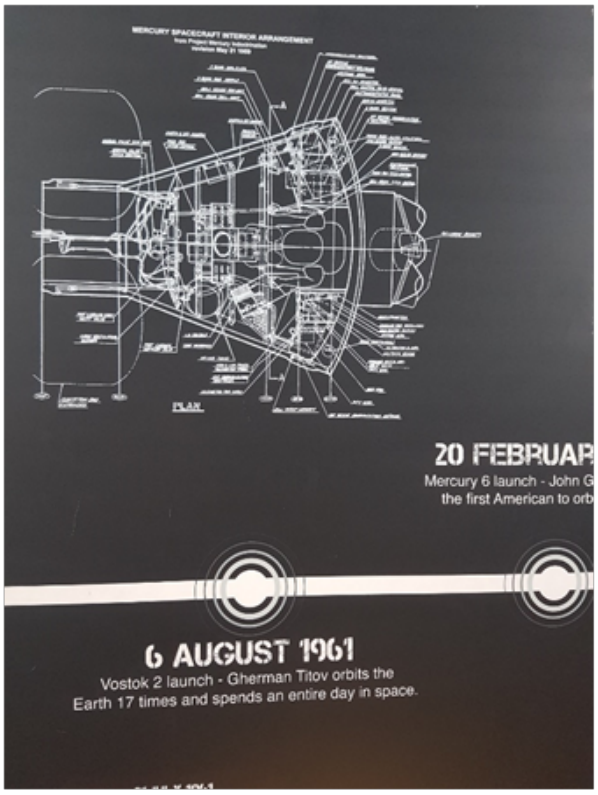

TRAINING MODULE 2.2 – LIFE SUPPORT
DEBRIEFING IN PROGRESS
WATER

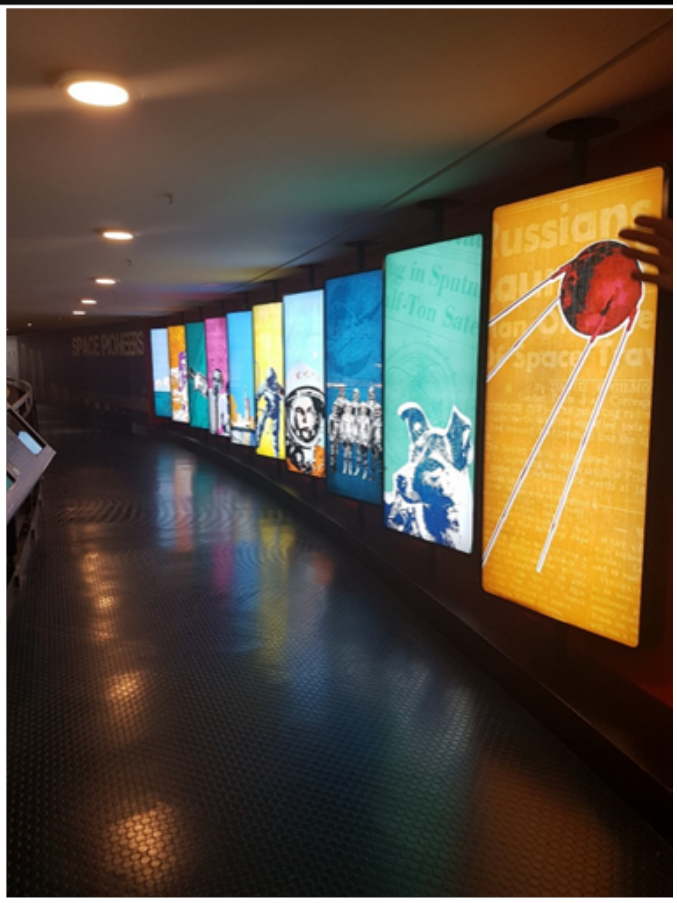

TRAINING MODULE 7 – SUPPLY STATION
Skip introduction
As Logistics Officer you have to select cargo to be transported

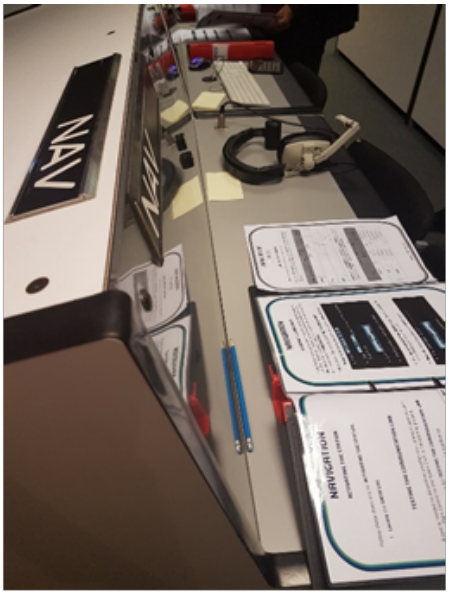

1967
1975


USSR
SOYUZ
ROCKET TOWER
SOYUZ


3

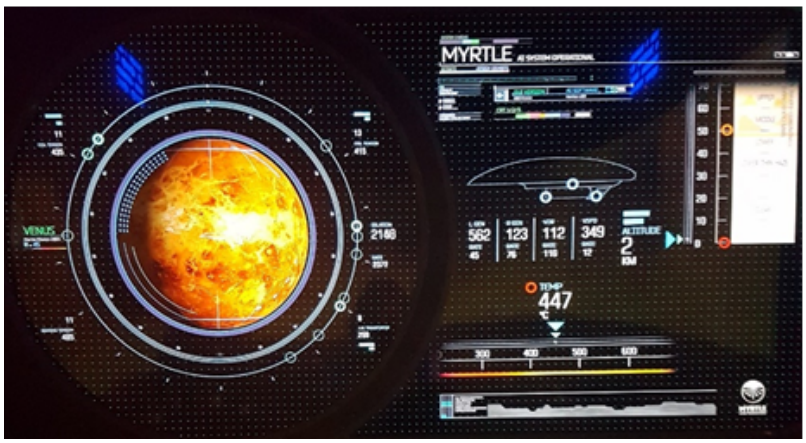

MERCURY SPACECRAFT INTERIOR ARRANGEMENT
20 FEBRUAR
Mercury 6 launch - John G
the first American to orb
6 AUGUST 1961
Vostok 2 launch - Gherman Titov orbits the
Earth 17 times and spends an entire day in space.




NAV
NAVIGATION


ISO 3
ISO 2
ISO 1


1,600 km
Land's End to
John O'Groats
975 km
Diameter of Ceres
2,390 km
Diameter of Pluto
1,000,000 metres


MYRTLE
562
123
112
349
2
447

4.3 M2M COLOUR SCHEME

The main colours used in the 'Mission to Mars' branding are black to represent space, white for text and accents, a yellow colour (#ff9933) and a red colour (#cc3333) to represent the 'red planet' Mars. The yellow and red colour will be used to create a gradient of orange to red tones (figure 19) that can also be used in branding and design.

Gradient (Roche, 2018)

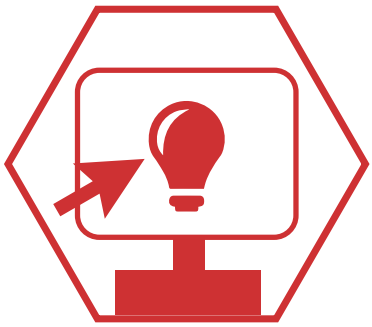
4.4 M2M LOGO DESIGN

A prototype logo has been produced and accepted for the duration of this project, allowing for components to be developed with consistent branding.

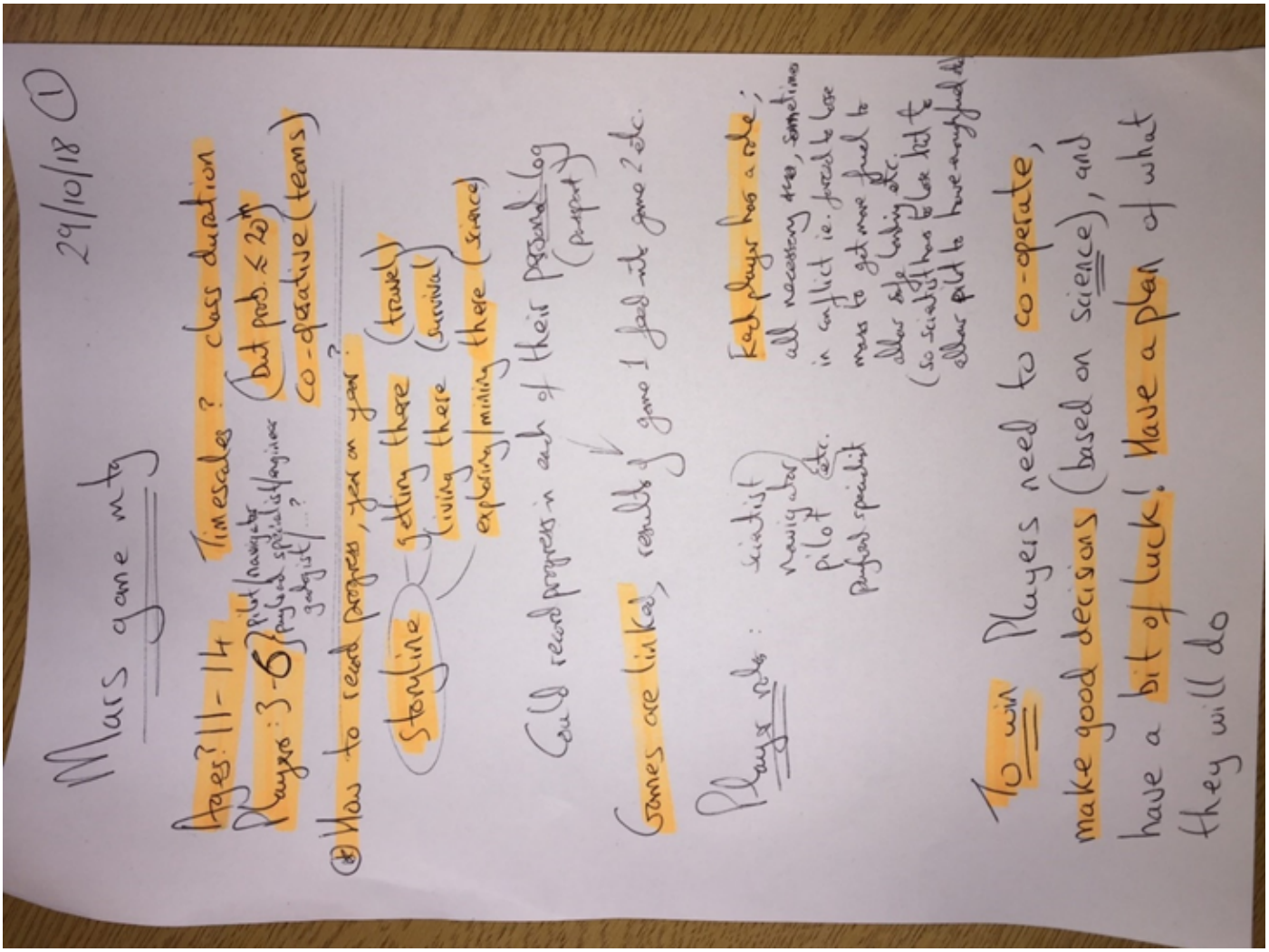
M2M logo (Roche, 2019)

4.5 BRAND VALUES

1. Approachable education
2. Cooperative learning
3. Accessible content (open-source)



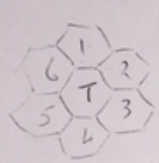
Figures 6.1 – 6.10 Game play and ideation meeting minutes



(3)

Card based?

No board (easier, cheaper) - have decks of cards for the key categories (NAV, HAB, Sci etc) - turn, trade, spend, use cards in each area to gain points (marked on cards).



or

target

Score by value of surrounding (6 or 9) areas?

Could be cards, or hex pieces?
(hex cards?)

Can have a pretty "Mars map" base where you lay cards on, but can play without it.

Key elements?

collaboration
teamwork
team work
negotiation

Start with "bad board" and cover with "good cards" as much as possible; random cards/events can spoil (or help?) - bad events can be countered by players spending/losing cards (cards like hit points/resources)

(2)

Build a map of an area of Mars

(select hab site
water
geology
rough terrain etc.

what science can you do?

then choose landing site within that terrain.

Points for each geology/water etc. tile, more points if closer to you

Crisis cards could add random terrain/events

Criteria for success? Score points for each of:

1. Landing (how accurate) (good/bad landing)
2. Habitat (Mars base) (big rough, rough for geology/water etc.) — life support
3. Science (how close to geology sites

Finite resources

spend to affect different aspects of the game
eg. focus more on navigation (fuel?) at the expense of science (less hit if more fuel)

"progress bars" to track how each category
eg. navigation - (L1) no mag field, compass no good
- (L2) build better instruments
- (L3) " are better "!

(5)

each square requires a certain combination of resources to get to; roll dice (2 dice for squares 1-3; 3 for 4-6; 4 for 7-9?)

(threat + counter) → Celestia has 4 different threats

solar flare → rock. suit etc.

Could have a deck of "danger" cards that cost a particular nrs. of resources

eg. Solar storm threatens: life (rock. suit) shielding
comms (hybrid electronics)
underground bunker etc.

Solar storm	counter with	1 Sci 1 HAB pt.
dust storm	"	1 NAV 1 HAB
meteorite strike	"	1 Sci 1 NAV

"Race to the top of Olympus Mons"

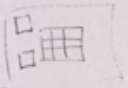
(4)

Cards can be used to build better board, or counter problems, or improve progress (progress bar)

Threat card: spit x pts (on cards) or take a random penalty (eg. replace random card of terrain deck with card from "bad terrain" deck)

final score = value of "board" @ end of game

Rubber mat board - image of Mars with spaces for "board" and draw deck, discard etc.



(so can be easily replaced or (live without it)

End of game? Set a time limit - Score @ end of 15m, 20m etc. is the final score

"Celestia-like" mechanic - but co-operative

Navigate from 1 Mars feature to another, pushing your luck (dice rolls) to see how far you go (how many points you get)

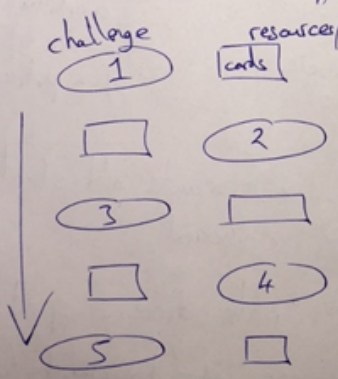
Collaborative system – everyone rotates around as commander + rolls dice + spends tokens/cards to deal with dice

Other players can contribute tokens/cards or help with their particular abilities

(but you are then spending finite resources from the overall pool.

When a mission "fails", the spaceship falls back to the point above the last completed stage.

Each stage/challenge is completed by spending a certain number of tokens/cards etc.



1 = rocket design/build

↓

5 = landing on Mars

2

Celestia-like game

29/10/18 evening (Andy, Paul, Corys)

1

Variable no. of stages – allows time to be varied

start | launch pad

(1) Rocket development □□

(2) Rocket launching □□

(3) Navigation to Mars □□

could be end (4) Orbit Mars □□□

end (5) Land on Mars □□□

reward cards picked up

dice rolled

more risky but ⇒ higher reward

spend resources to overcome each stage and "complete challenge"

Each player takes a specialisation

eg. pilot/navigator
engineer
scientist etc.

each role has a certain ability (or a no. of tokens of a particular type)

"Rocket model" (spaceship) – astronauts all start onboard

"Mission Commander" rolls dice – spends cards/tokens as required (to counter/cancel the dice symbols)

Rocket development = some COMP
+ some Sci
+ lots of MECH
(but no LIFE?)

(the LAUNCH = some COMP
+ " Sci
+ " MECH
+ " LIFE etc.

So the weighting of each challenge varies but is made up of the same 4 categories

"Pandemic" mechanism – need a particular combination of cards/tokens to solve the challenge eg. [10 MECH + 5 Sci + 5 COMP]

Have "wild cards" to help (can be used as any category)

Need to gather sets of tokens to overcome each challenge + "shut down" (overcome, complete) each one; no. of sets required increases as you get further up the challenges?

Can choose different starting conditions

eg. different crew configurations } different nos. of tokens or character skills/abilities
" starting technology etc.

Crises
- Mechanical — technical breakdown
- Science/Astronomical problem — solar storm, tech malfunction
- Life support
- Computer malfunction

challenge card

Card Title	eg. Rocket development
1 Mechanical problem	nos. of dice rolled (also no. of reward cards drawn)
2 Sci. problem	
3 LS problem	
4 Comp. problem	

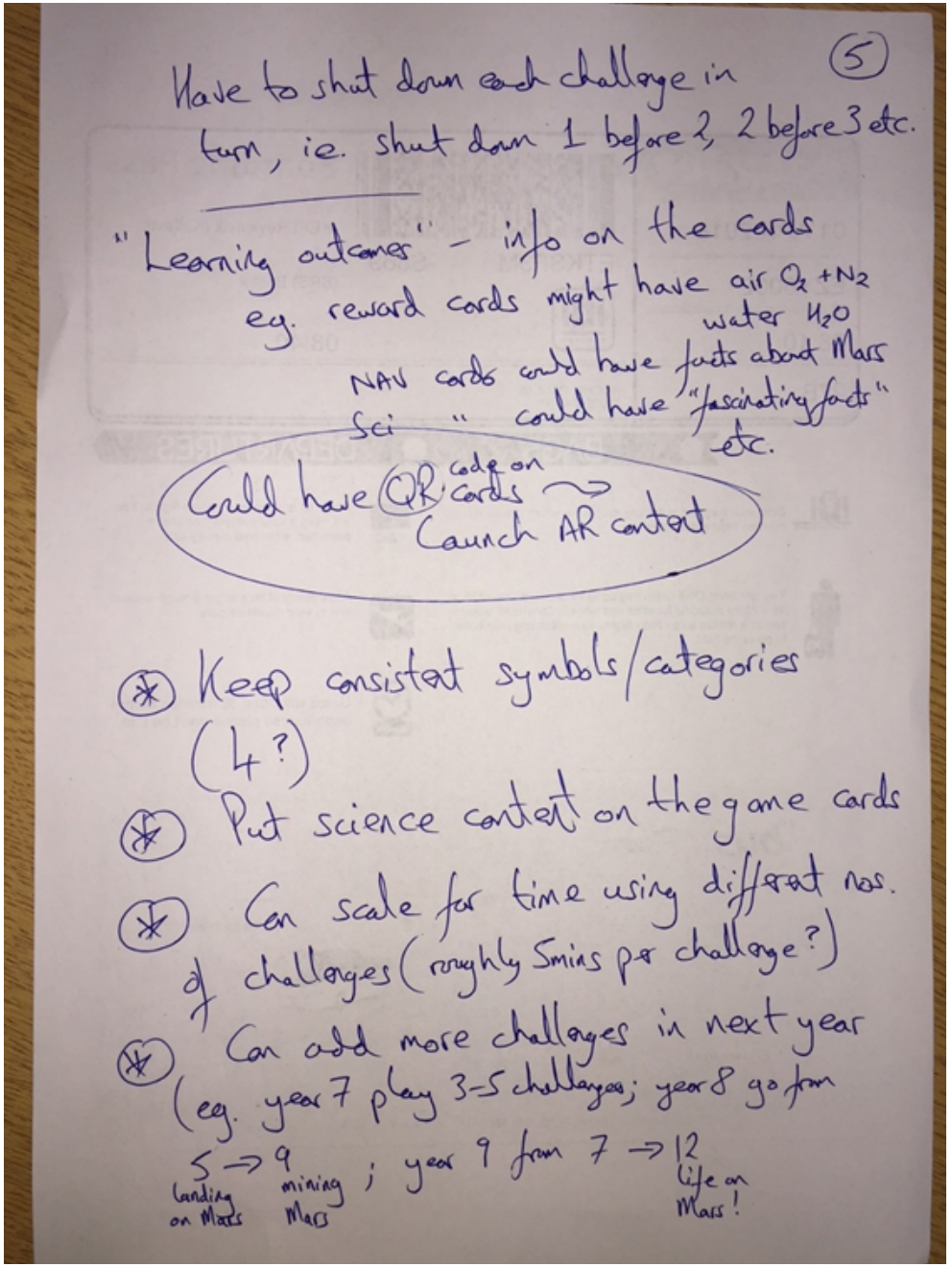
Have a dice with 4 (crisis) symbols + 2 blanks

Commander rolls 2 or 3 dice (as indicated on the challenge card)

Tokens/cards

Retain same 4 categories as for crises

eg. MECH
Sci
LIFE
COMP
} So each character/player has some ability in each of these areas, eg. Pilot might have Sci + COMP...



(5)

Have to shut down each challenge in turn, ie. shut down 1 before 2, 2 before 3 etc.

"Learning outcomes" - info on the cards
eg. reward cards might have air $O_2 + N_2$
water H_2O
NAV cards could have facts about Mars
Sci " could have "fascinating facts"
etc.

Could have QR code on cards → Launch AR content

* Keep consistent symbols/categories (4?)
* Put science content on the game cards
* Can scale for time using different nos. of challenges (roughly 5mins per challenge?)
* Can add more challenges in next year (eg. year 7 play 3-5 challenges; year 8 go from 5 → 9 ; year 9 from 7 → 12
5 → landing on Mars
9 → mining Mars
12 → life on Mars!

Figure 7.1 Participant Information Sheet

Participant Information Sheet

Study title:

Mission to Mars, Testing an Educational Board game

Invitation Paragraph:

You are being invited to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask me if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part. If at any point during the study you wish to withdraw you may.

What is the Purpose of this study?:

The purpose of this study is to test how easy and fun the proposed educational game is. Whether the rules are understandable and you can play a balanced game, that allows equal opportunities to all players and if it is beatable/losable.

Why have I been invited to participate?:

You have been chosen for this study as you are within the expected age range of game players and the educational information involved in the game is relevant to the curriculum you are currently expected to study.

Do I have to take part?:

As participation is entirely voluntary, it is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason.

What do I have to do?:

If you choose to take part you will join a group of up to four other volunteers to play a team based board game for one hour. Your play will be observed and comments you make while playing may be noted down. The study will all take place on one day and you will not be contacted again after this point.

Will my taking part in this study be kept confidential?

If you choose to take part all of your information will be kept confidential and destroyed after May 2019, with details being presented to Brunel University London.

What will happen to the results of the research study?

The research results will be presented in a formal dissertation report to Brunel University London.

Who is organising and funding the research?

The research is being organised and funded by Cerys Roche.

Who has reviewed the study?

Ethical consent for this study has been approved by Brunel Ethics Committee. Brunel University is committed to compliance with the Universities UK Research Integrity Concordat. You are entitled to expect the highest level of integrity from our researchers during the course of their research. Further information can be found on the Brunel University London research integrity webpage.

If you choose to take part all of your information will be kept confidential and destroyed after May 2019, with results being presented to Brunel University London. The results of this study may lead to the further development of an educational game to be played in KS3 science classrooms. If you wish for more information please contact me at 1507553@brunel.ac.uk

College of Engineering, Design and Physical Sciences Research Ethics Committee
Brunel University London
Kingston Lane
Uxbridge
UB8 3PH
United Kingdom

www.brunel.ac.uk

23 November 2018

LETTER OF APPROVAL

Applicant: Miss Cerys Roche

Project Title: Major Project

Reference: 13022-LR-Nov/2018- 14967-3

Dear Miss Cerys Roche

The Research Ethics Committee has considered the above application recently submitted by you.

The Chair, acting under delegated authority has agreed that there is no objection on ethical grounds to the proposed study. Approval is given on the understanding that the conditions of approval set out below are followed:

- The agreed protocol must be followed. Any changes to the protocol will require prior approval from the Committee by way of an application for an amendment.

Please note that:

- Research Participant Information Sheets and (where relevant) flyers, posters, and consent forms should include a clear statement that research ethics approval has been obtained from the relevant Research Ethics Committee.
- The Research Participant Information Sheets should include a clear statement that queries should be directed, in the first instance, to the Supervisor (where relevant), or the researcher. Complaints, on the other hand, should be directed, in the first instance, to the Chair of the relevant Research Ethics Committee.
- Approval to proceed with the study is granted subject to receipt by the Committee of satisfactory responses to any conditions that may appear above, in addition to any subsequent changes to the protocol.
- The Research Ethics Committee reserves the right to sample and review documentation, including raw data, relevant to the study.
- You may not undertake any research activity if you are not a registered student of Brunel University or if you cease to become registered, including abeyance or temporary withdrawal. As a deregistered student you would not be insured to undertake research activity. Research activity includes the recruitment of participants, undertaking consent procedures and collection of data. Breach of this requirement constitutes research misconduct and is a disciplinary offence.

Professor Hua Zhao

Chair

College of Engineering, Design and Physical Sciences Research Ethics Committee
Brunel University London

Cerys Roche
1507553
Design and Innovation, Management and Process
DM3801

BUSINESS PLAN

CONTENTS

THE BIG IDEA _____ 1-3

THE BUSINESS MODEL _____ 4-8
Segmentation 5
Value Proposition 5
Channels 5
Customer Relationship 5
Revenue Streams 6
Key Resources 6
Cost Structure 6
Key Activities 7
Key Partners 8

RISK ASSESSMENT _____ 9-10

REFERENCES _____ 11

THE BIG IDEA

The 'Mission to Mars' educational board game aims to be the first teaching resource developed by the Mission to Mars (M2M) brand as part of an update to science education in Wales. With science education being compulsory in the UK, and many other countries around the world, the expectation would be for teachers and students to be able to access a large array of supporting resources. Unfortunately, there are few options freely available.

With >100,000 games listed on their website, BoardGameGeek (2019) classify only 6.89%[1] of these as "educational". Of those, approximately one third are designed for children (BoardGameGeek, 2019). The M2M brand hopes to expand the selection available, seeing the benefits of tactile and social interactions in the learning environment.

M2M will offer these services to schools with minimum expense, meaning 'Mission to Mars' the game is purchasable as a finished product, but components are available for downloading and printing (both 2D and 3D) in schools. This feature also helps increase product lifespan and usability as it is less of a concern if parts are broken or lost, and game missions and cards can be regularly updated.

'Mission to Mars' is designed for year 7 classes (ages 11-12 years), as part of a wider shift in the Key Stage 3 (KS3) curriculum in Wales, following Donaldson's 2015 review of education (section 2.2). The game is themed around space exploration, specifically the

Figure 1 Children enjoying a board game together (Hip2Save, 2018)

STRENGTHS

- Encourages teamwork and cooperation
- Combines visual, verbal, physical (kinetic) and social learning styles
- Offers an alternative to rote memorisation teaching/learning tactics
- Can be updated and adapted to fit specific user/learning requirements
- Associates classroom-based learning with contemporary real-world events and technology

WEAKNESSES

- Relies on players to follow rules
- Relies on player concentration
- Limited time window for play due to lesson duration
- Best experience relies on having the opportunity to replay the game multiple times

OPPORTUNITIES

- Make the classroom experience more fun and exciting
- Build the confidence of players
- Make science education more engaging
- Increase interest and uptake of STEM subjects
- Can be produced in Welsh

THREATS

- Failure to test with the target market group
- Player disagreements leading to arguments
- Players becoming discouraged upon loss

stages required for a manned mission to leave Earth and reach Mars. It is played cooperatively as a team, with players working together towards the goal of reaching a Martian landing site.

Not only does the game engage students in physics and astronomy, it also helps develop wider skills, an area Donaldson highlighted as essential for children's development for successful futures. Some of the skills players will develop include communication, teamwork, problem solving, critical thinking and leadership.

[1] 7320 games out of 106242

POLITICAL:

- The law states that full time education is compulsory for all children between the ages of 5 and 16 (compulsory school age, CSA)
- Education is a devolved matter in Wales (and ~16% of students across Wales are educated in Welsh)
- Wales remains committed to the concept of community-based comprehensive schools
- Education in Wales is driven by a "producerist" model emphasising collaboration between educational partners (Reynolds, 2008)
- Lower funding in Welsh schools compared to England

SOCIAL:

- Playing board games considered 'uncool' by target market who have had exposure and access to video games
- Players who lack of confidence may dislike having to contribute and speak up in a group setting
- Students enjoy a break from "traditional" teaching methods
- Students benefit from peer learning, such as learning by teaching (instructing game moves or explaining game mechanics to others)

ECONOMIC:

- Welsh government provide WEFO grants for the development of educational resources
- Beneficiaries of EU funds
- The education industry is a large and consistent one, placing it within the top ten UK industries (Prime Office Space, 2014)
- Revenue in 2018 £47.7bn (IBIS World, 2018)
- Annual growth 1.5% (IBIS World, 2018)
- UK games market valued at £5.11 billion (12.4% growth in 2017) (Kempner, 2018)

TECHNOLOGICAL:

- Easy to run a website to advertise and sell the game, host downloadable player resources, updates, FAQs etc. making the game easy to distribute and support
- Online quotation services and manufacturers to order product components
- The availability of funding websites (e.g. kickstarter) to gain initial backing and interest in the product
- Increase in ownership of 3D printing technology

THE BUSINESS MODEL

SEGMENTATION:

The initial target market for 'Mission to Mars' the game are KS3 (specifically Y7, ages 11-12) students in schools across Wales. Research on the target user group is further discussed in section 2.9 ('The Target Market') of the dissertation. This player group were chosen due to an upcoming change in science curriculum and classroom approach in Wales. Y7 is the transition age between primary and secondary school for most UK children, and can result in a lack of confidence and growth of self-doubt in students who have found themselves in a large, new environment.

In terms of the use market, 'Mission to Mars' is aimed at schools, meaning it has been designed and developed to be played in the classroom as part of a lesson. The game is mainly being marketed at teachers, schools and councils. However, this does not rule out having a commercial option available that can be purchased and played at home by students, gamers or science hobbyists.

VALUE PROPOSITION:

The core values of M2M are:

1. Approachable education
2. Cooperative learning
3. Accessible content (open-source)

The aim is not only to increase interest and engagement in STEM subjects but also to develop students' skills in a way that helps prepare them for successful futures. M2M will lead to classroom content having stronger ties to what is happening outside of schools, and into the wider world and beyond.

Schools and students should be able to access educational resources freely, therefore an important aspect of the 'Mission to Mars' game is having all the necessary content online, free and downloadable. While people can choose to purchase a copy of the game at a higher quality value, broken or lost parts can easily be replaced through use of printers and 3D printing technology. An online resource also provides a place to update and expand content in the future, keeping what the students are learning in school connected with real-world events and technology.

CHANNELS:

Conversations with members of Cardiff Commitment (Cardiff Council Education) have allowed for the project to have access to comprehensive secondary schools across Wales. M2M will collaborate with a large scale, EU-funded programme ('UniverseLab') which schools will already have a relationship with, 'Mission to Mars' will initially be introduced to schools across south Wales, reaching ~1,200 students and their teachers.

Relationships will be further developed by providing users access to a website on which they can freely access the game information and components, and additional educational resources. It will encourage the sharing of student work such as mission badge designs and articles written about Mars, potentially linking one teachers' idea for a follow-up and teaching activity with other teachers. This will not only build a relationship between the brand and user, but also amongst the users themselves, creating a sense of community.

Other ways of reaching the market include promotion at relevant educational conventions or events and word of mouth amongst teachers. Academic events are good way to market directly to schools and teachers, allowing for conversations about the pedagogical benefits and content.

CUSTOMER RELATIONSHIP:

M2M will develop a long-term, ongoing relationship with users. Providing constant updates and expansions for the initial board game, as well as allowing the user to purchase (or download and print) new components at any time. This (and the plan for future outreach games) makes M2M a service that can constantly provide new educational resources to its users.

The hope is that customers, especially teachers, will also build relationships with each other, creating an M2M community of those that use the product(s), sharing their experiences and ideas for ways to adapt the game for different user groups, along with their students work (e.g. crew badge designs and essays). M2M will not just provide users with the latest space-based news and education resources but will also

benefit from a dialogue with them, inspiring new ideas and educational tools.

There will be a constant open dialogue between the company and the intended user market, leading to a co-creation relationship, with the first game already being designed with future users in mind (as shown with the teacher interview in dissertation section 2.3). Further games would be developed with the input of students by running workshops once M2M is an established name in the school.

REVENUE STREAMS:

The main initial source of funding for M2M will come from STEM education grants. Several options exist for grant applications, including the Science and Technology Facilities Council (STFC) who provide public engagement funding opportunities such as Spark awards[2], with starter grants up to £15,000.

Smaller sums can be obtained from other organisations, including education/outreach grants up to £5,000 from the Royal Astronomical Society (RAS)[3] or £10,000 from the UK Space Agency[4]. As a Wales-focused project, applications can also be made to Institute of Physics Wales[5], where start-up funds (up to £750) can be gained relatively informally, and larger sums up to £3,000 can be applied for via formal schemes. All these grant schemes are highly focused on space education funding, but there are other education-based grants available that would also be appropriate funding options for this project.

Another revenue option is Kickstarter[6], a global crowd funding platform for creative projects. There have been a wide array of successful board games backed on this site in the past. Backers would receive a copy of the game along with bonus perks, such as M2M merchandise and game expansion packs, that could include additional player characters, new missions/cards etc. Kickstarter is also a great way of marketing, growing awareness of the product to those who it may interest.

KEY RESOURCES:

Key resources used during the development of this product are the brand 'UniverseLab' (section 4.0) and the scientists, gamers and educational professionals that have been involved in the process, from the background research through to the game development. Further human resources were used when playtesting the game, and more play testers (from the target market) will be required for future testing.

3D printers are an essential resource for this game, in order to produce the 3D components, and printers will be needed to make the cards and mission tiles. However, the most important resource will be the website, mission2mars.net. This will be how users interact with the company and each other, as well as access to the component files and additional content. However, funding will be needed to bring all these resources together.

COST STRUCTURE:

M2M is a value-driven brand, aiming not to achieve the minimum costs but to deliver a meaningful experience. Any potential profits, following salaries, will be invested back into the brand for the development of further educational resources. The most important expenses for the game will include human resources. First, hiring a professional illustrator to design the initial deck of cards and then any following cards or expansions. It will not be until this is done that a commercial version of the game can go on sale. This version of the game will require an investment in additive manufacturing and printing services for batch manufacture, or the potential consideration of injection moulding if the game will be mass manufactured.

The open-source version of the game requires an investment in a website, including purchasing a domain and employing a web or UX/UI designer. Following this there will be the need for continual upkeep of the website, including writing blogs and game fact/mission updates.

[2] https://stfc.ukri.org/public-engagement/public-engagement-grants/pe-funding-opportunities/stfc-public-engagement-spark-awards/
[3] https://ras.ac.uk/awards-and-grants/outreach/education-outreach-small-grants-scheme
[4] https://www.gov.uk/government/publications/space-for-all-community-funding-scheme-2019
[5] http://www.iopwales.org/activities/public/
[6] https://www.kickstarter.com/

KEY ACTIVITIES:

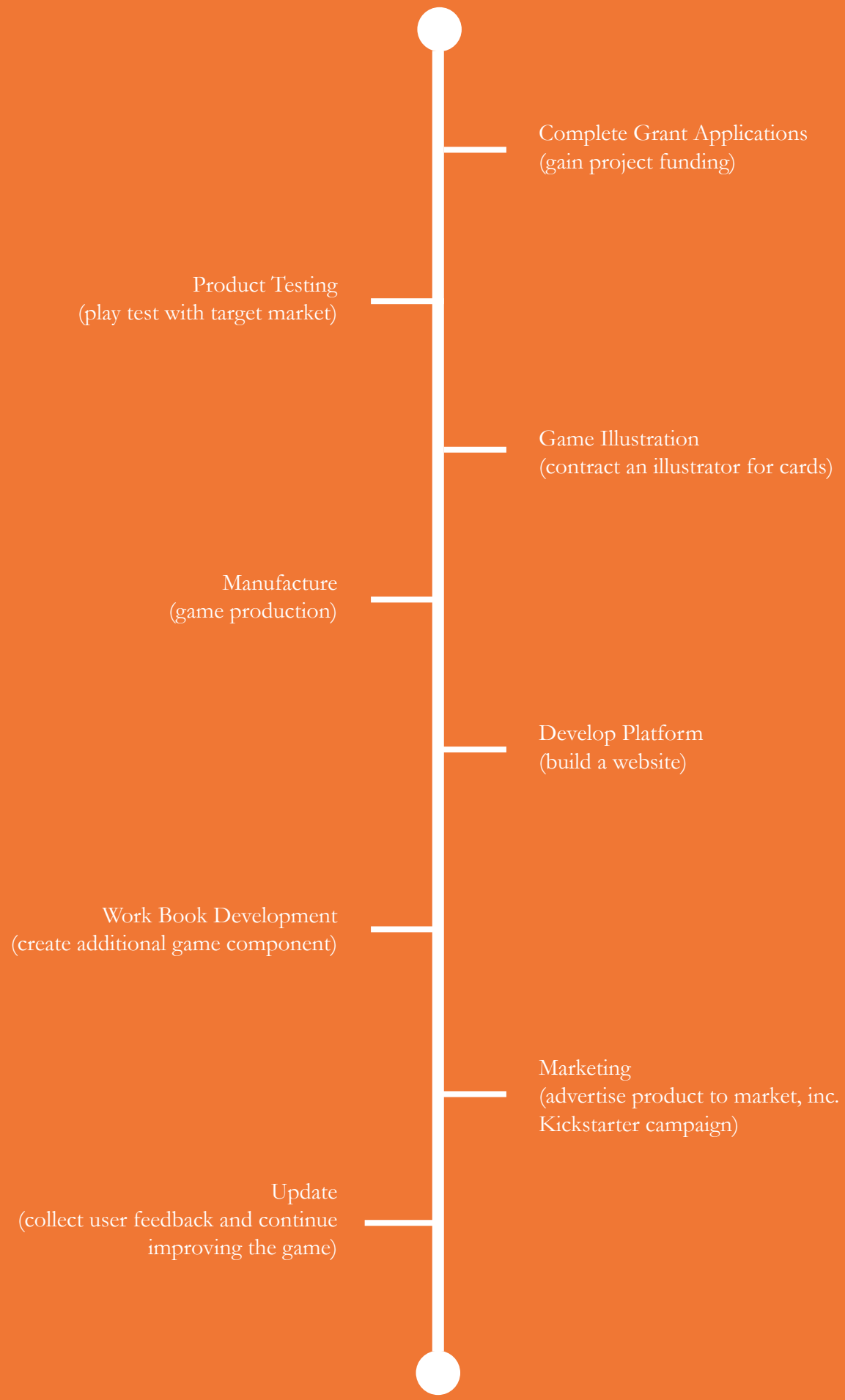


Figure 2 Timeline of key activities

KEY PARTNERS:

Cardiff Commitment:
Provide access to schools in Cardiff and information on upcoming curriculum changes, along with an insight into the classroom environment.

Cardiff School Teacher:
Created and provided the 'Mission to Mars' lesson plans and gave an insight into the Y7/KS3 science classroom environment.

School of Physics and Astronomy (Cardiff University):
A source of physics and astronomy information, fact-checking game content was accurate and to a scientific level appropriate for the target market.

Board Game Shop:
Provided an insight into the world of boardgames and gamers, along with suggesting a variety of games and game mechanics to consider (sections 2.6 and 6.1).

Target market play testers to help with final adaptations to the game and the final users (e.g. school teachers and students) that will help build the community online and provide feedback

RISK ASSESSMENT

Risks in gameplay are discussed in table 8, section 6.2.2 (Potential Game Issues).

RISK	EFFECT	IMPACT ON PRODUCT EXPERIENCE (/10)	PROBABILITY OF OCCURRENCE (/10)	CONTINGENCY PLAN
M2M not adopted by enough schools	A community of users not built Few students experience the educational and developmental benefits Limits the future funding needed for developing more resources	7 9 6	4 4 4	Have the game available commercially for hobbyists to play. Do not limit the game to use only within the classroom environment. Budget for sets of game updates within the initial funding applications.
Components cannot be manufactured cost effectively	Game is not feasible for self manufacture Commercial game is highly expensive	7 7	2 4	Allow for users to adapt the game parts or use alternatives (e.g. bottle tops as player pieces).
Product is too expensive for schools	Will not be adopted by schools or schools will only purchase one copy	9	4	Provide discounts for purchases by educational professionals/ institutes. Provide discounts for bulk purchasing.
Paper cards rip or stain	Cards are marked or untidy Cards become unusable	3 6	7 4	Have multiple copies of cards so game is still playable. Provide templates or blank cards so that they can be easily replaced.
Player piece legs snapping in production or delivery	Difficult to keep game piece on the board spaces as it will not stand up	7	4	Widen the section where the rockets legs join the main body.

Mars pieces not fitting securely into the Mars landing site	Less satisfying interaction between components, the pieces are more likely to fall out if the game is knocked	5	3	Design components with tolerance, prototype the parts to make sure they fit together.
Printer errors on cards or mission tiles	Less easy to read information Unreadable parts	6 10	3 2	Provide the full set of missions and card deck online, in order for users to print at home. Find a well established printing company to manufacture the components, trusting in their experience to create error free components.
Lack of funding	Cannot provide the game as an open source educational resource, must become a purely commercial product	9	5	Apply for a variety of grants and start a Kickstarter scheme to have as many revenue stream options available as possible.
Teachers not allowing for multiple play sessions	Students do not benefit from the education and skills development as intended	8	6	Make the game a length that will fit into a lesson without taking over. Provide teachers with information on the education value of playing the game multiple times and create a lesson plan and activities around the game play.
Users not learning from playing the game	The game is not an educational tool and is taking away from valuable teaching time	5	3	Create a game that is fun to play, resulting in increased enthusiasm for the subject, increasing student engagement in future lessons. Provide a follow up activity/work book for students to complete, that will require them to reflect upon and potentially research the educational game content.
Failure to meet standards for toy safety	Game cannot be aimed at children under the age of 14	10	2	Research the necessary BSI standard (EN 71) and refer back to it throughout the design development.
Component does not last, is lost or broken	Limits the playability of the game	5	5	Have all components available for free download so that replacement parts can be locally produced.

Table 1 Product risk assessment

BIBLIOGRAPHY

BoardGameGeek, 2019. Board Game Geek. [Online]
Available at: https://boardgamegeek.com/
[Accessed 8 April 2019].

Hip2Save, 2018. Double Ditto. [Online]
Available at: https://hip2save.com/2018/11/29/amazon-double-ditto-family-board-game-only-11-97-shipped-awesome-reviews/
[Accessed 14 April 2019].

Kempner, S., 2018. UK games market grows 12.4% to a record £5.11bn in 2017. [Online]
Available at: http://ukie.org.uk/press-release/2018/03/uk-games-market-grows-124-record-%C2%A3511bn-2017
[Accessed 8 April 2019].

Prime Office Space, 2014. The Top Ten Industries in the UK. [Online]
Available at: https://primeofficespace.co.uk/latest/top-ten-industries-in-uk/
[Accessed 19 October 2018].

Reynolds, D., 2008. New Labour, Education and Wales: The Devolution Decade. Oxford Review of Education, 34(1), pp. 753-765.