

Games-Based Learning as an Interdisciplinary Approach to Literacy across Curriculum for Excellence

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Abstract

Literacy remains an area of concern in early secondary education in Scotland (ages 12-14), with recent research suggesting a continued decline in attainment levels. As literacy underpins learning, interdisciplinary and collaborative approaches to teaching literacy are now being emphasized through the new Curriculum for Excellence that aims to address this issue. It is not clear, however, what types of learning activity are most appropriate for implementing this new, more cooperative approach. One candidate is the use of educational games and reflective writing. So, to what extent do learners demonstrate transferable literacy skills through engaging with educational games? This paper evaluates the effectiveness of the multi-user simulation game, Mars Colony Challenger (MCC), which portrays a scientifically accurate Mars colonisation mission in a way that aims to facilitate both scientific and literary development. A class of secondary school pupils (n=28) used the game within the context of a science class on 'The Three States of Matter'. They then produced written narratives that captured the experiential learning undertaken. Comparing these narratives with the remaining pupils in the cohort, who had not used MCC in their science class, revealed a statistically significant difference in literacy ability. Further qualitative analysis of the narratives themselves highlighted a high level of engagement and inspiration evoked through the experience. Consequently, these results highlight the efficacy of MCC as a means of literacy development, and they suggest a means to elicit greater frequency of opportunity for pupil engagement with, and subsequent assessment of, literacy competencies.

Keywords

Literacy; Curriculum for Excellence; Interdisciplinary Learning; Science; Game-based learning; Digital games; Serious games

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1. Introduction

According to the 2012 and 2014 'Scottish Survey of Literacy and Numeracy' (The Scottish Government, 2013 & 2015) levels of attainment in writing continue to decline. As stated by the Department of Education (2012) there is a paucity of evidence as to why writing lags behind the other literacy competencies and research has not provided evidence as to what interventions help secondary pupils succeed in written competency.

The importance of writing proficiency cannot be underestimated. Emig (1977 in Thompson, 2012) contends that the teaching and learning of writing has a foundational and underpinning role in children's development:

Writing serves learning uniquely because writing as process-and-product possesses a cluster of attributes that correspond uniquely to certain powerful learning strategies (p. 122).

In order to tackle this problem, a new *Curriculum for Excellence* (CfE) has been introduced in Scotland. Part of the CfE strategy is an interdisciplinary and collaborative approach to literacy education. Accordingly, it is now within the remit of all teaching professionals to embed the overarching themes of literacy into their daily practice. Literacy – reading, writing, speaking and listening – is:

Fundamental to all areas of learning, as it unlocks access to the wider curriculum. Being literate increases opportunities for the individual in all aspects of life, lays the foundations for lifelong learning and work (LTScotland (2012a), p. 4).

Lawless & Brown (2015) assert in their paper on digital game-based science and literacy learning: "researchers have illustrated for decades that leveraging interdisciplinary contexts... provide opportunities for students to engage in real-world problem solving that can deepen students' understanding, flexibility in application and transfer of knowledge to novel situations and also reduces the likelihood of inert knowledge (e.g., Bednar, Cunningham, Duffy, & Perry, 1992; Bransford, Vye, Adams, & Perfetto, 1989; Brown & King, 2000; Jonassen, 2009; Koschmann, Kelson, Feltovich, & Barrows, 1996; Mergendoller, Bellisimo, & Maxwell, 2000) (p. 4)".

This paper presents the outcomes of an action research project that was undertaken within the context of *Curriculum of Excellence*, a series of interdisciplinary lessons between the Science and English Departments of a Scottish secondary school. The target population was a pupil cohort in their second year (S2) of post-compulsory education. S2 pupils are

13-14 years old and have been studying English as a compulsory subject since they were 4-5 years old (Primary 1). Therefore, this project was quasi-experimental since all pupils in S2 study English.

Pupils utilised a networked, multi-user digital game in order that they could write personal and imaginative narratives within the English and Science curriculums, utilising all four competencies of Literacy independent of the subject area.

2. Games, Play & Learning

In addition to the widening responsibility for Literacy, *Curriculum for Excellence* it has extended the definition of what constitutes a 'text'. In the document 'Curriculum for Excellence: Literacy and English. Principles and Practice' (LTScotland, 2013a) under the section 'What is meant by 'texts' (p. 4) the traditional "novels, short stories, plays, poems" are now joined by the now ubiquitous multimodal and digital mediums - "blogs and social networking sites...text messages...games" (ibid.) - of the 21st Century.

Digital games, themselves cultural texts (Buckingham & Burn, 2007; Salen, 2007 in Altura & Curwood 2015), are composed of distinct yet interconnected elements: graphics, sound, interface, gameplay and story, as defined by Berens and Howard in Newman (2004), whereas traditional narratives exhibit the "sequential nature of language (you read or hear one word at a time)" (Greenfield, 1984, p. 101). Games provide the opportunity for parallel processing and therefore mimic the real world where there are "multiple interacting variables...the world is not a simple system, but rather many complex systems of multiple interacting factors" (Greenfield, 1984, p. 103; Blunt, 2013).

Simulation games allow for 'real' experiences to be recorded simultaneously, enabling pupils to provide an imaginative element to their experiences. With the affordance of a multi-player context, these activities may be undertaken within "a group that is bonded primarily through shared endeavours, goals, and practices" (Gee, 2003, p. 197), providing richer shared corroborative narratives.

Wouter *et al.* (2013) in their meta-analysis of 39 previous studies concluded that 'serious games' were effective in improving both learning and retention. Connolly, *et al.* (2012) also found that during their meta-analysis of game-based learning that the most frequent instances of efficacy were related to understanding and acquisition of content knowledge.

Mars Colony Challenger (MCC) offered an experience analogous to the establishment of a sustainable human colony on Mars. The physical and scientific constraints would determine the survival of both individuals and groups. The loose 'scriptedness' of the game allowed for creativity

in the pupils' final written pieces while accommodating the adoption of scientifically accurate information and an understanding of the natural process involved.

3. Mars Colony Challenger

Mars Colony Challenger (MCC) is a 3D first-person video game, developed by Hyperkat Games¹ in the USA, that offers players the challenge of setting up a remote base on the surface of Mars. At its core, the game was derived from a simulator where everything is fully integrated. The developer took a scientific approach in order to develop an authentic experience drawing upon accurate principles and technologies, resulting in a game that is both educational and challenging.



Figure 1. In-game footage from *Mars Colony Challenger* of the water pumps installation.

Using this networked, multi-user application, pupils collaborated in separate teams consisting of no more than four players². Of the game's seven phases, only 'Phase #1: Establish Life Support' was played by pupils as it was supported by the Science and English-based curricular activities and would involve pupils in learning about the processes associated with the 'three states of matter' (LTScotland, 2012b) – solid, liquid and gas. 'Stage 1: Water Pumps' requires that players locate, assemble and activate two heated water pumps to melt subsurface ice, and produce a water supply; 'Stage 2: Separator' requires that players

¹ <http://www.hyperkat.com/>

² Some groups (e.g. G and H) occasionally produced a combined grouping of 5 players.

locate, assemble and enable the Separator Unit which extracts oxygen and hydrogen from the newly established water supply (the hydrogen is used to fuel a utility rover vehicle); 'Stage 3: Scrubber' requires that players locate, assemble and activate the Scrubber Unit which mixes the oxygen with carbon dioxide and nitrogen from Mars' low pressure atmosphere to create a breathable atmosphere of 14-psi within the base.

It was important to build upon the use of MCC to support pupils in the development of their personal narratives. Pupils began to think about their 'destination' and garnered the necessary and realistic back-story (Kane, 2004) for the first two weeks, working within their designated groups, encountering non-fiction and fiction texts aimed at creating the imaginative backdrop, and which posed the themes:

- What is Necessary to Support Life on Earth?
- How Could Mankind Colonise Mars?

An existing BBC book and DVD series (BBC, 2004) was used as the narrative backdrop (Royle, 2008; Newman 2004) against which their virtual personas could be "stimulated or scaffolded by external elements" (van der Meij *et al.*, 2011) and operate in "both fictional and non-fictional" realities" (Barab *et al.*, 2005, p. 16). Sitzmann (2011 in Wouters *et al.*, 2013) suggests evidence that when "a simulation game was supplemented with other instructional methods [it] yielded higher levels of learning." This was not the case when the game was used on its own.

After engaging with related Science concepts, fictional and non-fictional pieces about Mars and an imagined manned exploration, pupils were expected to produce a final personal-imaginative piece of writing that captured their experiences 'on' Mars, and elicit an understanding of the science behind establishing a small human colony.

4. Research Methods

Within this paper, the following research question is addressed:

To what extent do pupils demonstrate transferable literacy skills through writing reflective pieces about their experience in a game-based learning activity presented in the context of science-themed English lessons?

For the purpose of this experiment, the sampling frame consisted of second year (S2) classes of male and female pupils aged between 12 and 14 at a Scottish school. The experiment encompassed the academic term between January and April 2014 and was aimed at exploring the introduction of the Mars simulation software package, Mars Colony Challenger (MCC). Its effectiveness as a 'mediating tool' in satisfying a number of curricular outcomes for English, Literacy and Science through inquiry-based, experiential learning activities in "an open-ended journey towards understanding" (Kane, 2004) is measured as the dependent variable, while the use of MCC is the independent variable. The rest of the pupils in the year group – the control group – undertook prose-related activities involving short stories chosen by their class teacher.

Because of school management restrictions random sampling could not be achieved and it was possible only to draw a sample of 30 pupils (17 female and 13 male) from a cohort of 132. The experimental group was one class taught by a single teacher. The control group included four classes taught by four different teachers.

The 30 pupils were distributed into 6 groups of 4 (Groups A-F); and there were 2 groups of 3 (Groups G and H). Group construction was undertaken with attention afforded to (where possible):

- evenly-matched gender pairing;
- behaviour management and/or Guidance Department stipulations³;
- attainment (Science and English assessment data from S1);
- the anticipated peer-support.

The pupils in the control group were similarly of mixed ability and therefore showed varying degrees of competency across subject areas; pupils are not set according to ability at this academic stage.

³ It is not uncommon that the Guidance Department – often acting upon a parental request – will issue directives for certain pupils to be separated from each other within classrooms: historic instances of bullying, etc. Separation of pupils is also undertaken by classroom teacher in order that misbehaviour between individuals is limited.

4.2 Data Collection

Qualitative and quantitative data were derived from the main corpus of pupil work as follows:

- Interim journal writing and group discussion
- Final personal-imaginative writing

4.2.1 Quantitative Data

The final personal-imaginative written piece contains the personal-imaginative narratives that were a montage of the pupils' experiences of the 'Mars 2050 Colonisation'. The pieces were assessed using a subset of the Curriculum for Excellence *Literacy and English Experiences and Outcomes* (LTScotland, 2012a).

Each writing outcome is ascribed an 'I Can' statement, and these marking descriptors range from *Second* (2), *Third* (3) and *Fourth* (4) in ascending complexity in confirming competency in a particular aspect of a piece of writing. For example, Figure 2 shows spelling competencies (LIT *-21a) required for a piece of work to be given either a category *Second* (2), *Third* (3) and *Fourth* (4).

Second	Third	Fourth
<p><i>I can spell most of the words I need to communicate, using spelling rules, specialist vocabulary, self-correction techniques and a range of resources.</i></p> <p style="text-align: right; color: #e91e63;">LIT 2-21a</p>	<p><i>I can use a range of strategies and resources and spell most of the words I need to use, including specialist vocabulary, and ensure that my spelling is accurate.</i></p> <p style="text-align: right; color: #e91e63;">LIT 3-21a</p>	<p><i>I can use a range of strategies and resources independently and ensure that my spelling, including specialist vocabulary, is accurate.</i></p> <p style="text-align: right; color: #e91e63;">LIT 4-21a</p>

Figure 2. Literacy – Writing – Spelling: -21a.

Each piece of writing was first graded under three Literacy (orthographic) outcomes, each of which would be assigned level 2, 3 or 4. And each piece of writing was then graded under two English (form and content) outcomes each of which would be 2, 3 or 4. Final narratives were then assigned three levels: an aggregate level for LIT; an aggregate level for ENG; and an overall aggregate level which was the LIT and ENG aggregates combined.

The English ('ENG') Outcomes (Figure 3) required further definition during the purposes of coding and the development of a richer narrative analysis for this project, and Fisher's (2012) classifications (Table 1) were used.

Second	Third	Fourth
<p>As I write for different purposes and readers, I can describe and share my experiences, expressing what they made me think about and how they made me feel.</p> <p style="text-align: right;">ENG 2-30a</p>	<p>I can recreate a convincing impression of a personal experience for my reader, sharing my feelings and reactions to the changing circumstances with some attempt at reflection.</p> <p style="text-align: right;">ENG 3-30a</p>	<p>I can create a convincing impression of my personal experience and reflect on my response to the changing circumstances to engage my reader.</p> <p style="text-align: right;">ENG 4-30a</p>
<p>Having explored the elements which writers use in different genres, I can use what I learn to create stories, poems and plays with an interesting and appropriate structure, interesting characters and/or settings which come to life.</p> <p style="text-align: right;">ENG 2-31a</p>	<p>Having explored the elements which writers use, I can create texts in different genres by:</p> <ul style="list-style-type: none"> • integrating the conventions of my chosen genre successfully and/or • using convincing and appropriate structures and/or • creating interesting and convincing characters and/or • building convincing settings which come to life. <p style="text-align: right;">ENG 3-31a</p>	<p>Having explored and experimented with the narrative structures which writers use to create texts in different genres, I can:</p> <ul style="list-style-type: none"> • use the conventions of my chosen genre successfully and/or • create an appropriate mood or atmosphere and/or • create convincing relationships, actions and dialogue for my characters. <p style="text-align: right;">ENG 4-31a</p>

Figure 3. Literacy – English: -30a & -31a.

Fisher's definitions in Table 1 expand on characterisation, setting, as well as personal reflection and interaction and allowed for a broader analysis of the communal aspects of the pupils' colonisation activities.

CfE	Fisher (2012)	Elaborations
Literacy (LIT)	<i>Orthographic</i>	Spelling, Punctuation, Paragraphing, Meaning.
English (ENG)	<i>Form</i>	Word Choice, Sentence Construction, Figurative Language.
English (ENG)	<i>Content</i>	Setting Description, Personal Reflection, Emotional Response, Interpersonal Relationships.

Table 1. Coding from Fisher (2012).

Two English Department colleagues volunteered their support to assess the samples of final personal-imaginative narratives: one with more than twenty years' experience, and the first 'Chartered Teacher⁴' in the school; the other, a Probationer Teacher⁵. The Science Teacher reviewed a selection of final narratives, assessing the scientific content.

⁴ Introduced in 2003, The Chartered Teacher was a new qualification-based teacher grade focusing on enhanced professional practice and effectiveness in teaching and learning.

<http://www.gov.scot/Publications/2003/07/17538/22895>

⁵ A graduate based in a school and who is working through the process of becoming a fully qualified teacher.

4.2.2 Qualitative Data

In education "collaborative group activity is the key to promote student interaction in the classroom" (Hashim & Jones, 2007) and to aid capturing such events, Cultural Historical Activity Theory⁶ (CHAT) was used. CHAT, proposed by Engeström (1999 & 2001) is used to encompass the social contexts of learning: 'rules', include grammatical and genre rules, science principles, lesson plans, game rules; 'community' refers to the pupils participating in the same 'object' or 'outcome' and the other organisational hierarchies related to this system; 'division of labour' refers to the degree of contribution provided by activity participants, pupils and teacher. Whilst primarily a data analysis tool used to describe systems of human activity, the collection method was informed by this conceptual lens and assisted through the use of a template (Hardman, 2008) that helped capture the disorganised and complex data associated with "multi-mediational processes in human activity" (Yagamatchi-Lynch, p. 25, 2010).

Other material that allowed for a qualitative analysis of the project was drawn from questionnaires (e.g. how they rated the game and which features were most enjoyable; how they rated the BBC Space Odyssey DVD clips and text; group interaction) and semi-structured interviews. Additionally, there were observations of social interaction during game play, since players' "reaction to game play, or debriefing, is one of the key stones of the research programme of many recent studies on video games" (Guillén-Nieto *et al.*, 2012) and analysed using Cultural Historical Activity Theory (CHAT).

Data was collated pertaining to each of the interpersonal 'activity systems' that were manifest during the use of the MCC game and during other periods of collaborative group work; identification of initial codes and subsequently-derived themes were undertaken in accordance with the methodology presented by Strauss & Corbin (1990), Corbin (1998) & Saldana (2012), allowing the production of the rich qualitative narratives that were used to explore each dynamic system of activities. Such qualitative studies of the social and affective aspects of digital game-based learning are encouraged by Connolly et al (2012).

⁶ CHAT is an augmentation of Vygotsky's concept of 'mediation' known as 'Activity Theory' (AT). AT conceptualizes "learning as activity and activity as learning" (Engeström, 1999 in Barab *et al.*, 2002, p. 5) and describes the inextricable link between learning and acting: "activity (sensory, mental, and physical) is a precursor to learning (Jonassen & Rohrer-Murphy in Barab *et al.*, 2002, p. 80).

4.3 Data Analysis

Mann-Whitney U was used to compare the MCC experimental group and the control group because the data were ordinal and did not follow a known distribution. In addition to the quantitative data analysis, the qualitative analysis was driven by theory (Hamalainen *et al.*, 2006, p .52) and utilised the processes of Yagamatchi-Lynch (2010) and Hardman (2008): producing CHAT diagrams for important scenes within episodes of gameplay; coding key scenes using CHAT terminology. During the course of pupils' engagement in the in-game activities, CHAT was the theoretical lens used to analyse how each – MCC, science fiction and non-fiction texts, workbooks, etc. – operated as a 'mediating' tool. Pupil relationships and the division of labour within each activity system were highlighted, as were the dialogic and written artefacts produced during the transformations occurring as subjects (pupils) engaged in attaining their objectives and outcomes.

The final versions of pupils' personal-imaginative narratives, in addition to the re-viewing of video evidence and questionnaire data that had been transcribed and coded facilitated qualitative descriptions of the "rich participant activities" (Yagamatchi-Lynch, p.33 , 2010) and the implications and perspectives for the future use of the MCC software.

Using CHAT methodology, game-based interaction and non-game based classroom activities – traditional classroom activities and group interviews – were analysed to "determine tensions which emerged through the blended learning experience" (Karasavvidis, p. 198, 2009). Tensions can affect the subject's ability to attain the object by taking a role as an obstacle, making it difficult for the subject to attain the object, or by taking a role as an enabling influence for the subject to attain the object" (Yagamatchi-Lynch, p. 18, 2010).

Game analysis was conducted by transcribing key events from the audio and audio-visual recordings of 'over the shoulder' observed lessons as well as group discussion interviews. *Transana*⁷ was used to facilitate the 'coding' process using CHAT and collate supplementary data that related to other aspects – enjoyment, interaction, frustration, etc. – obtained through periodic logging of performance and achievements.

5. Results

5.1 Quantitative Findings

5.1.1 Final Writing Levels

Two of the 30 pupils failed to submit the final pieces of personal-imaginative writing: absences and the loss of interim written material

⁷ <http://www.transana.org/>

were the major factors and as such attrition should be factored into any secondary school context. The results for the experimental group using *MCC* ($n=28$) were then compared with the control group ($n=102$).

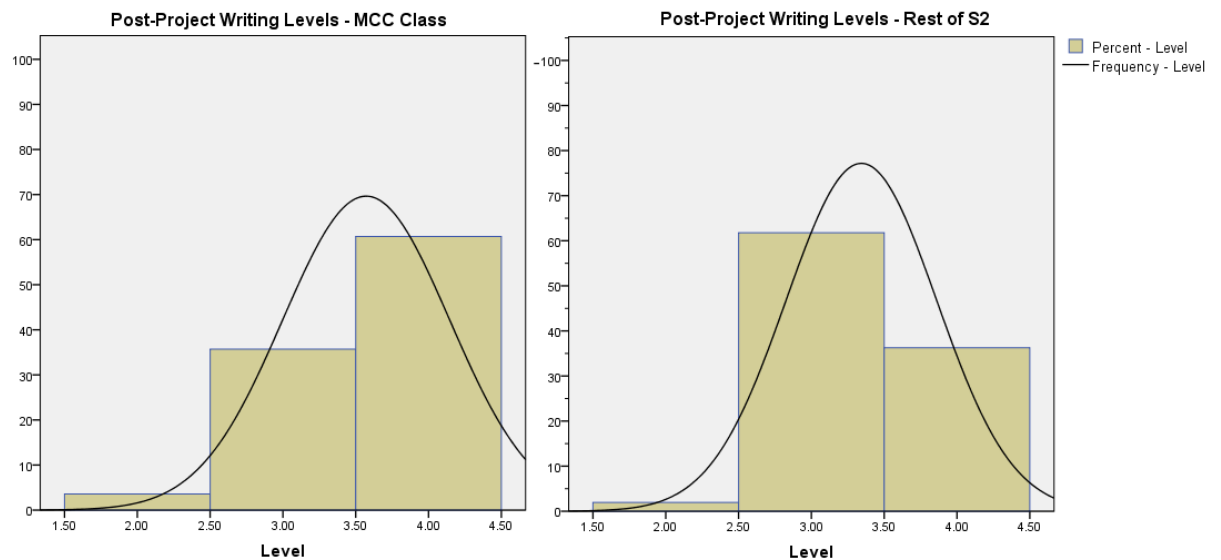


Figure 4. Histogram showing the post-project performance writing levels of pupils involved in the *MCC* project and the control group

In Figure 4 the graph on the left is skewed to the right, showing a significant trend in the performance of the pupils involved in the *MCC* project. The majority of these pupils attained levels between 3.50 and 4.50. In contrast, the second graph is skewed to the left, showing that the majority of the pupils independent of the *MCC* project attained levels between 2.50 and 3.50.

Comparatively, the control group performed better than their year group peers. Although the lack of a true control group disallows for asserting causal claims about the impact of *MCC* on writing attainment – the corollary 'Baseline (2013)' levels are unavailable for the rest of the year group – the results do support that the simulation has facilitated development in writing.

Ranks			
Cohort	N	Mean Rank	Sum of Ranks
Experimental group	28	77.20	2161.50
Control Group	102	62.29	6353.50
Total	130		

Test Statistics⁸	
	Level
Mann-Whitney U	1100.500
Wilcoxon W	6353.500
Z	-2.140
Asymp. Sig. (2-tailed)	.032

Table 2. Results of Mann-Whitney Test comparing experimental group and control group final writing levels

A Mann-Whitney U Test revealed a statistically significant difference between the experimental group and the control group, as shown in Table 2. From this data, it can be concluded that there is a difference in distribution between those pupils who were involved in the *MCC* project and those who were not, with those using *MCC* having a higher probability of achieving a higher rank than their peers.

⁸ Grouping Variable: Cohort

5.2 Qualitative Findings

There remains a disparity between competency in English and Literacy Outcomes. For instance, Pupil-11 (Group-D), despite orthographic issues (achieving a Level 2 in LIT 2-22a⁹, punctuation, varied sentence structures, and paragraphing) was still able to demonstrate effective word choice:

33:28¹⁰ not enough resources
 33:30 locate
 33:32 fully installed
 33:33 different objectives
 33:34 connect

Table 3. *Atlas.ti* Quotations for Effective Word Choice use by Pupil-11 Group-D

To illustrate, consistent sentence construction – punctuation, for example – is inconsistently applied and remains an issue in the case of Pupil-1 and Pupil-15, despite the astute form and content exemplified:

"The sky looks like butter scotch and I have a dry mouth because it's so hot we have no water yet because we haven't installed the water pumps" (Pupil-1, *Atlas.ti*, Primary Document P81).

"...for us to take the kit of, It took a while because to install the scrubber you need a scrubber unit compressor..." (Pupil-15, *Atlas.ti*, Primary Document P65).

This was a general feature across most of the groups: Pupil-8 and Pupil-11 of Group-D similarly displayed lapses in sentence construction – especially punctuation (full stops) despite displaying aptitude in form and content. Further peer- and self-assessment should resolve such frequent lapses; this supports the necessity that all curriculum teachers provide the interventions to correct orthographic issues, when pupils can produce writing that is engaged and purposeful.

⁹ *Curriculum for Excellence: literacy and English. Experiences and Outcomes* (p.8, LTScotland, 2012a)

¹⁰ A quotation is a segment from a Primary Document (PD) that is interesting or important to the user. The PDs in this project refer to the pupils' final narratives, and the depicted quotations relate to the result of Boolean queries. The format used is: (Primary Document Number : Quotation Creation Order).

In Group-A, as with the other groups, the activities resulted in the adoption of strong verb usage, verbs that suited the identities that were co-constructed during the activities they were carrying out on Mars; verbs and language that constructed the social aspect of the character and his/her imagined character's back-story on Earth. For example, the first block contains language that constitutes their scientific and engineering identity:

38:14 tightening
 38:15 installing
 38:18 (which had been deployed earlier)
 68:18 Unpacking and setting
 68:11 rendezvous
 82:15 well heads

Table 4. *Atlas.ti* Quotations for Strong Word Choice/Verb use by Group-A

The second block contains language that constitutes their personal identity:

38:27 (my favourite horse at my riding school.
 38:40 you could see a faint light
 68:8 it feels like a life jacket but.
 82:17 [Pupil-1] is the funniest of the group.
 80:15 I am nervous about staying here.
 80:16 I am missing home very much just now.
 80:18 I got barely any sleep last night.

Table 5. *Atlas.ti* Quotations for Form and Content use by Group-A

As is present in the other group writing pieces, we have a mixture of 'mission jargon' and language that is creative and rich in delivering personal and imaginative narration from multiple identities.

Here we have the application of a real-world adjectival ('heavy') to what is essentially the object of a digitally simulated activity:

"We installed the water pumps yesterday. They were quite *heavy* but we managed to get them fixed onto the tops of the well heads. It took most of the day to install both of them, it was hard work but rewarding because we can now pump water up from under the surface of mars" (Pupil-7, *Atlas.ti*, Primary Document P87).

"[Pupil-7] and [Pupil-27] were doing all the heavy lifting, bringing the equipment that we needed inside from the garage the installing the *bulky* pumps. I and [Pupil-28] were the ones who

were preparing the separator inside the base for tomorrow's work" (Pupil-29, *Atlas.ti*, Primary Document P81).

Apart from Pupil-7, all the pupils in Group-B attained the highest Level 4 in ENG 3-30a (Personal) and ENG 3-31a (Imaginative) as a result of their richness and "convincing and appropriate structures and/or...interesting and convincing characters" (Education Scotland, 2004, p. 17).

Royle (2008) suggests that players engage if:

The backstory or narrative provides the believability or authenticity of engagement.

Characterization makes the player's role in the narrative believable so that the player can engage fully in the game.

From Group-B, Pupil-29 demonstrates the hybrid nature of narratives that originate from game-play and thinking imaginatively:

"Thinking back, my favourite moment on Mars was when our first plant broke the rocky surface: the first Martian plant ever to have been grown by humans. I think the only moment to compete with that moment was when I went to check on the fish eggs on morning and our first fish had hatched; they were so small, having seen them on Earth I would never have had thought that they would have been the first Earth species to have been born on Mars" (Pupil-29, *Atlas.ti*, Primary Document P81).

6. Discussion

6.1 Experimental group performance

The use of the digital game, *Mars Colony Challenger* (MCC) and a limited set of text-based and audio-visual resources have supported 28 of the initial 30 pupils in expressing themselves in both imaginative and personal writing, which displayed improved attainment between 2013 and 2014.

Pupils involved in the project achieved a mean literacy level of 77.20, whereas the control group achieved a mean of 66.29. The data supports the assertion that there is a significant statistical difference between the two groups (one of the project limitations was having no access to 2013 'baseline' levels for the control group) and that the adoption of a digital game has successfully operated as a 'text' as specified by *Curriculum for Excellence*.

6.2 Science Curriculum Planning & Instructional Design

The final personal-imaginative narratives show overall progression in writing for all pupils. Despite the constraint of having no formally-timetabled Science lessons to coincide with the project timeline, pupils remained appreciative of what they were attempting to learn.

Future timetabling to complement the narrative events encountered in *Mars Colony Challenger* events, and an awareness of the asymmetric distribution of the tasks within the game and its impact on the acquisition of learning scientific processes – and associated nomenclature – would enrich future collective story-telling that is obviously at the kernel of this digital game.

Mars Colony Challenger (MCC) - and similar games - should be employed and be externally supported by lessons that maintain a realistic and relevant scientific pedagogy, so that teachers can develop in their pupils "reflective practice, analysis, and evaluation, all essential high-level skills in today's information-based society" (Royle, 2008). In Jackson (2009) the author notes that "Prensky (2001a) ties the power of stories to the evocation of emotion" (p. 297) and Royle (2008) asserts that:

Storytelling is a potent learning tool:

Stories are a powerful communication tool because they enable listeners to make connections between what is said and their own experience — this helps create meaning and can trigger people into action. (Bonner, Chartier, and Lapointe 2006, p. 4)

Science should recognise that “narratives enable students to develop research skills, critical and creative thinking... related to managing and utilising scientific knowledge in everyday life” (Vrasidas *et al.*, 2015, p. 3). Steinkuehler and Duncan (2009) observed evidence of such higher-order cognitive skills in episodes containing sophisticated ranges of language during discussion between digital game players, which included the use of content knowledge in constructive argumentation and reasoning. Having pupils participate in the creation of such stories using games like *Mars Colony Challenger*, when supplemented by other methods of instruction, and which afford pupils to work in groups can be more effective with regards to learning and content retention (Wouters, *et al.*, 2013; Vrasidas *et al.*, 2015; Connolly *et al.*, 2012) . Furthermore, when there was an underlying “theme that is loosely related to the learning goals [it] may improve the effect of a narrative” (p. 12).

However, with regards to the Clark/Kozma debate, which continues to question the efficacy of media in enhancing learning - “that no single media attribute forms a unique cognitive effect” (Clark, 2007 in Becker 2010), this article suggests that the use of a computer simulation does facilitate ‘learning by doing’ (Schank *et al.*, 1999) but that responsibility for such successful implementation “must be placed squarely on the shoulders of both [digital games and instructional design]” (Becker, 2010).

6.5 Diegesis – Were they *there*?

English Departments stand to benefit from opportunities whereby pupils write both imaginatively and from experience of a text such as MCC:

“When [Pupil-15] turned her light on her space suit you could see a faint light down the hill!” (*Atlas.ti*, Primary Document P38)

As part of the qualitative data gathered, there was evidence from questionnaires and interviews that pupils enjoyed the MCC project and the group-based activities derived from it; it is clear that the activities in MCC “originate logically from the narrative structure of the game” (Royle, 2008) which itself is rule-based and grounded in scientific laws: “Opportunities to promote storytelling should be maximised in the Game Design” (ibid).

Pupils’ identity as Mars Colonisers within MCC was through what they were actually doing and at the same time reflecting upon their current (or imagined) personal lives – far from home, missing family and pets, acknowledging frustration with their fellow crewmembers. Such learning within the context of a game “involves taking on and playing with identities... There is a tripartite play of identities as learners relate, and reflect on, their multiple real-world identities, a virtual identity, and a projective identity” (Gee, 2003, p. 67). This is also supported by Vrasidas *et al.* (2015) and their use of the Science Fiction genre to

introduce interdisciplinary learning of Science, stressing the importance “of narratives in involving the reader in the story emotionally” (p. 2), as well a pointing to research by Avraamidou & Osborne (2009) that supports the multiple cognitive benefits “the introduction of narratives in science education significantly increases students’ memory, interest, and understanding” (ibid):

I’m missing my family and of course my beloved horses from Velvet Path...I brought my bracelet I made of Juniper’s mane to remind me of them. Even in space, horses smell the same so I am still a bit homesick... Yesterday we did our first orbit refuelling when we had just arrived...one of Mars’ two moons, Deimos,

passed in front of us. What a majestic sight!

...

Today we worked much better as a team than yesterday as we completed the water pumps, scrubber (which was to make the air breathable), and sabieter (which mixed together the right chemicals for fuel for the rover).

...

I then began to shutting down the machines after I made sure everyone had their space suits on. We made sure nothing had been left behind and slowly made our way outside.

We took our final steps on Mars and boarded the lander.”

(Pupil-14, *Atlas.ti*, Primary Document P38)

From the pupil narratives the high proportion of occurrence of the exclusive pronoun ‘we’ supports – and corroborates – the societal aspects of the lessons. ‘We and ‘they’ allows pupils to reflect on events from their own and the perspectives of others; they consider others, their contributions and the social dynamics of their group – all in a safe context, proven to have generated little if any angst amongst its members.

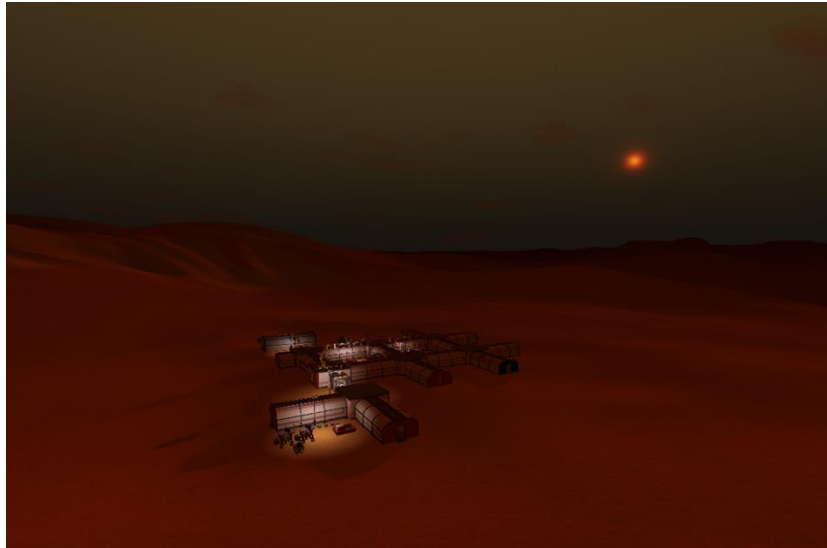


Figure 5. In-game footage from *Mars Colony Challenger* - the base at night.

6.6 Limitations

A limitation of this study was the unavailability of baseline data for the entire cohort of S2 pupils, which would have been used to, firstly, control for prior experience, and secondly, provide insight into the gains made by pupils of different levels of ability. Furthermore, due to the lack of random allocation of students to experimental and control group, the research was quasi-experimental in design. While the author has no reason to believe that this class differed meaningfully from the control group, follow up studies that confirm these results using a more rigorous experimental design are advised.

6.7 Future Research

The MCC project activities are clearly enculturated into the written and spoken language of the pupils involved: the *MCC* simulation software provided a “flexible learning context in which students both work independently and collaboratively as they complete game tasks” (Spires, H., 2015, p. 5). From the qualitative results, a number of future considerations are suggested in relation to the spoken and written language associated with engagement with a digital simulation for learning: an analysis of the performance of pupils in the individual elements of ‘Eng-’ and ‘Lit-’ based on gender and ability.

The compilation of a body of personal-imaginative corpora from game play involving MCC should continue, and support a deeper linguistic analysis of the personal-imaginative narratives. Of interest will be an exploration of the interplay of the ‘I’ and ‘We’ pronoun frequencies with regards to pupil attainment and game engagement. This computation of collocations based on pronoun use and lexical variety is of particular interest, and may reveal correlations whereby greater lexical richness

associated with pieces of writing that are drawn from the recall of specific episodes in the digital game; the impact of group collaboration and discussion on written lexical variety and richness should also be considered (Charsky, 2010 in Guillén-Nieto *et al.*, 2012).

Furthermore, an exploration of the use and acquisition of scientific language could lead to isolating game episodes that provide the richest imaginative responses and evidence of scientific content knowledge within the loose narrative structure, which would provide Science teachers and English teachers with clearer evidence of areas facilitating collaboration.

7. Conclusion

Within the context of the *Curriculum for Excellence*, the sciences and other subject areas must now share responsibility for pupils' literary development. Science teachers are, therefore, afforded a new collaborative role in helping pupils to actively engage with texts, enable pupils to access the wealth of literary genres that the scientific disciplines offer, and facilitate opportunities for literacy assessment. However, it is not clear how science teachers can design learning environments that will help students develop transferrable literacy skills.

This paper has explored the use of the educational simulation game, *Mars Colony Challenger*, as one possible approach. The results of an experimental trial showed a statistically significant difference in literacy ability between those pupils using the game and those who did not.

Literacy must be supported by other subject specialists; problems with orthographic ability cannot be eradicated simply by the introduction of a digital game. But game-based learning, such as the activities undertaken with *Mars Colony Challenger*, can support writing across many disciplines.

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