Cases on Digital Game-Based Learning:

Methods, Models, and Strategies

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Chapter 26
Racing Academy:
A Case Study of a Digital Game for Supporting Students Learning of Physics and Engineering

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EXECUTIVE SUMMARY

Racing Academy is a digital game, which is specifically designed to engage and motivate students in science and engineering. The aim of this chapter is to report a case study where the authors evaluated how effective Racing Academy is at supporting students' learning of science and engineering. The study involved 219 students from five different courses in three further and higher educational institutions. They were given a pre-test a week before they started using Racing Academy. It consisted of an assessment of the students' knowledge of engineering or physics and motivation towards engineering or physics. A week after they had used Racing Academy, they were given a post-test, which was the same as the pre-test, but it also included a measure of how motivating they found Racing Academy. The project found that after playing Racing Academy there is an increase in students' knowledge and

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understanding in all five of the courses in which Racing Academy was used. The students found Racing Academy motivating to play, and 95% thought that Racing Academy was successful. The implications of these findings and the lessons learnt are discussed.

INTRODUCTION

Science, technology engineering and mathematics (STEM) is seen by the USA and by the UK as essential for their long term economic futures (DfEL, 2009; Engineering UK, 2009; US NSB, 2007), which has led to a drive to improve STEM education (National Research Council, 2010; National Science Board, 2010). In pursuit of this aim, there has been considerable interest in using digital games for supporting STEM education for a number of reasons. First, a number of reports have shown that digital games have become an integral part of life for children and adolescents. In a recent survey of US adolescents, 98% of teenagers played digital games (Lenhert, Kahne, Middaugh, Macgill, Evans & Vitak, 2008) regularly at least once a week.

Second, well designed digital games can provide powerful learning environments (Gee 2005, FAS 2006, Mayo 2007, 2009). The Federation of American Scientists (FAS, 2006) identifies the following reasons why digital games could facilitate students' learning in STEM.

- They are highly motivating (Kafai, 2001) and research has consistently shown that high levels of motivation leads to high learning outcomes.
- They provide clear learning goals and players know why they are learning something.
- Players are presented with a range of experiences and practice opportunities.
- They are learning in a complex challenging simulated world rather than learning a set of abstract facts devoid of real world context.
- The lessons can be practiced over and over again.
- Video games continually monitor player's progress and provide feedback which is clear and often immediate.
- Video games move at a rate that keeps players at the edge of his or her capabilities moving to higher challenges when mastery is acquired.
- They are infinitely patient and can offer scaffolding, providing learners with cues, prompts, hints and partial solutions to keep them progressing through learning until they are capable of directing and controlling their own learning path.
- They encourage inquiry and questions and respond with answers that are appropriate to the leaner and context.

Furthermore, Gee (2003, 2005) and Shaffer, Squire, Halverson & Gee (2005) both argue that digital games have the potential of placing students in simulated environments where they face authentic, open ended challenges similar to those faced by actual professionals. Gee (2005) argues that when individuals play these type of digital games experience first hand how members of a profession think, behave and solve problems, thus they are engaged in a deep, meaningful learning experience. Shaffer et al., (2005) argue that too much of classroom learning is about understanding symbols divorced from the concrete reality of those symbols. In the virtual worlds of games learners experience the concrete realities of what those words and symbols represent. They can understand complex concepts without losing the connection between the abstract ideas and the real problems they can be used to solve. Shaffer et al., (2005) conclude that one reason computer games are powerful learning environments is because they make it possible to develop situated understanding.

Recent research appears to confirm the benefits of digital games for supporting situated learning. Coller & Scott (2009) developed a racing car game which they used to support students learning of numerical methods in an undergraduate mechanical engineering course. They found that students taking the game based course spend roughly twice as much time, outside of class, on their course work. They showed greater depth of understanding of the relationship between concepts and they were very interested in a further follow up course. Mayo (2009) reports that digital games can increase learning in STEM between 7% to 40% compared to traditional lecture based courses.

The aim of this chapter is to report a case study which investigated the use of a digital game, called Racing Academy, to support students' learning of engineering and physics in further and higher education. We evaluated the effectiveness of Racing Academy and interviewed both the students and the lecturers to explore their experiences of using a digital game for supporting their learning and teaching. The analysis of the interviews led us to identify a number of challenges faced by both the students and lecturers which impacted on the effectiveness of Racing Academy. Finally we discuss the lessons learnt from this case study.

PRACTICALITIES OF RUNNING RACING ACADEMY

Racing Academy was specifically designed to engage and motivate students in science and engineering. It aimed to achieve this by engaging them in tasks that were authentic, that involve real practice and through which they can see the effects of their choices, interventions and actions. It is based on a real-time vehicle dynamics simulation system, which is capable of recreating the experience of driving any automobile. It accurately models in real-time how cars behave and react. The games engine has the capacity to allow users to manipulate over 1,000 vehicle parameters, which is particularly important because it enables the students to change the vehicle parameters (such as the engine, transmission, tires and suspension) in order to optimize vehicle performance. Through this optimization process the students get a better understanding of the system dynamics that influence behaviour. Players must engage with the underlying physics and work as a member of a team where practice arises out of real physics and involves the social negotiation of understanding.

The game has three levels and a race level. In the first three levels, players race a computer controlled opponent ("the AI driver") along a quarter mile drag strip (See Figure 1). Every time they beat the AI driver they move on to the next level and the races typically last between 11-15 seconds.

In level 1 the player is given the choice of changing the controls, changing the color of the car and a choice of one of six engines. In level 2 the players have a choice of tires and in level 3 the players can change the gear ratios. After level 3, the students can access the Race level. The Race level has a test circuit and a skid-pan. The skid pan was designed to test the handling characteristics of the car, in particular under steer and over steer (See Figure 2).

At this level, the students can change 12 different characteristics of the car, as well as the engine, the tires and the gear ratios. On the test circuit, they compete against themselves to obtain the quickest time around the test circuit. Racing Academy can be downloaded free from the following website: www.racing-academy.org

DETAILS OF USING RACING ACADEMY FOR TEACHING AND LEARNING

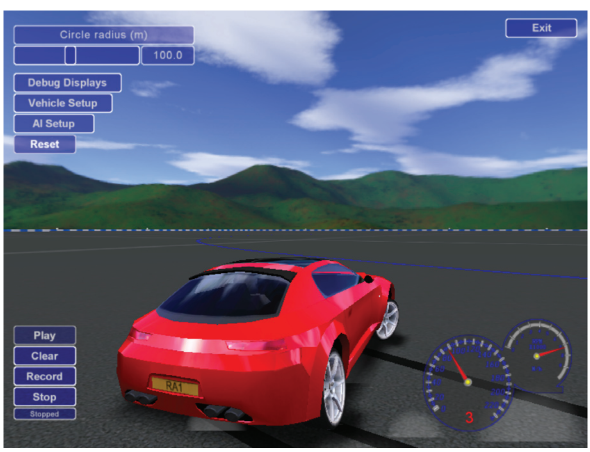
At the start of the project, we held a design workshop with the lecturers and the Racing Academy Design Team. The outcome of this meeting was a number of suggested modifications to Racing Academy. Racing Academy was used in two further education colleges and one university. At Barnfield Further Education College, it was used in the IMI Nationals: Motor Vehicle Engineering course. Fifteen students took this course and they were all male and had an average age of 17 years. It was also used in a BTECH Motor Vehicle engineering course. Eighteen students (17 males and 1 female) took this course, their average age was 19.0. At Penwith Further Education College, Racing Academy was used to support 15 students' learning on the AS/A2 level courses in Physics. There were, all male and they had an average age of 17 years. At the University of Bath, it was used to support two courses in

Figure 1. Drag strip

the Department of Mechanical Engineering: a first year course on solid mechanics (average age 19, 143 males and 15 females) and a final year course on Vehicle Dynamics (average age 22, 14 males and 1 female).

Racing Academy was used as part of the students' course and the students were organised into racing teams consisting of 3 to 5 students. The teams designed a racing car in Racing Academy which was used to compete in the drag race for the best time. Each team had their own private discussion forum, where they could discuss how best to set up their car. Engineering support was provided through an open discussion forum. The project lasted two weeks and at the end of two weeks there was a grand final where the teams raced against each other and there was a prize for the winning team.

Figure 2. Skidpan



The aim of all the lecturers involved in the project was to try and increase their students' engagement in their courses and in doing so support and enhance their students' learning.

EVALUATION

We evaluated Racing Academy by using a pre-test administered a week before they started playing with Racing Academy and a post-test the students completed a week after they had finished using Racing Academy. The pre-test consisted of an assessment of the students' knowledge of engineering or physics and motivation towards engineering or physics. Three different aspects of motivation towards engineering or physics were measured and these were enjoyment of engineering or physics, perceived competence in engineering or physics and how important engineering or physics was to them personally. Students answered the questions using a five point Likert scale ranging from 1 strongly disagree to 5 extremely agree.

The post-test was exactly the same as the pre-test, but it also included a measure of how motivating they found Racing Academy. We asked them how much they enjoyed playing Racing Academy, how good they were at playing Racing Academy, how much effort they put into playing Racing Academy and how valuable playing Racing Academy was in their studies. The students answered it using a five point Likert scale, ranging from 1 strongly disagree to 5 extremely agree. Finally we asked the students how often in the previous week they had played Racing Academy, how often they read the message boards and how frequently they posted messages on the message boards. The students answered this with a five point scale ranging from, 0 never to 4 several times a day.

First, we looked at how frequently students played with Racing Academy. They were playing it at least once a week at Barnfield and several times a week at Penwith (See Table 1). We found that students were playing Racing Academy more at college than at home. The message boards were not being used so frequently, with the exception of the students at Penwith Further Education College.

There is a big difference how frequently students use Racing Academy between the two courses at the University of Bath (See Table 2). Students were playing Racing Academy several times a week in Solid mechanics and less than once a week in Vehicle Dynamics.

The questionnaire for the courses at Bath did not distinguish between playing Racing Academy at Home and at College

Next we evaluated how much students learnt from playing Racing Academy. We measured learning in terms of the difference between the number of questions they answered correctly on the pre and post-test measures (See Table 3). There were

Table 1. Frequency of playing Racing Academy at Penwith and Barnfield

	At College		At Home		Reading message board		Posting Messages	
	M	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**
Barnfield IMI Nationals	1.2	0.4	0.7	0.4	0.7	0.4	0.4	0.5
Barnfield BTECH	1.3	0.6	0.5	0.6	1.0	0.6	0.4	0.6
Penwith AS/A2 Level Physics	2.0	0.0	0.4	0.5	1.5	0.5	1.0	0.6

Table 2. Frequency of playing Racing Academy at Bath

	Play Racing Academy		Reading message board		Posting Messages	
	M	**SD**	**M**	**SD**	**M**	**SD**
Bath Solid Mechanics	2.1	0.8	1.5	0.8	0.5	0.8
Bath Vehicle Dynamics	0.5	0.5	1.0	0.7	0.5	0.5

Table 3. Pre-test and post-test scores for the 5 courses

	Pre-test		Post-test			
	M	**SD**	**M**	**SD**	**t**	
Barnfield IMI Nationals	21.4	7.3	22.7	5.5	1.6	
BarnfieldBTECH	16.5	4.6	20.3	5.5	2.0	*
Bath Solid mechanics	7.7	2.5	9.2	2.8	9.1	*
Bath Vehicle Dynamics	2.7	1.5	3.9	1.7	3.0	*
Penwith AS/A2 Level Physics	7.9	2.8	10.6	2.1	4.7	*

* $P < 0.05$

statistically significant improvements in solid mechanics, vehicle dynamics, BTECH motor vehicle engineering and AS/A2 level Physics. There was an improvement in the IMI Nationals vehicle engineering course, but this was not statistically significant.

One of the key aims of the project was to encourage and motivate engineering and science students. Before the students played Racing Academy we measured 3 different aspects of motivation towards physics or engineering. These were how much students enjoyed physics or engineering, how competent they perceived themselves at physics or engineering and how important physics or engineering was in their life. We also measured their motivation after they had finished using Racing Academy for their courses (See Table 4).

We found no significant improvement in students' motivation towards physics or engineering (See Table 4), however it is evident from the means that the students already had high levels of motivation even before the project started.

We assessed how motivating students found Racing Academy by using the following four scales: (1) how much they enjoyed playing Racing Academy, (2) how good they were at playing Racing Academy, (3) how much effort they put into playing Racing Academy and (4) how valuable playing Racing Academy was.

There were a number of similarities and differences between the four courses concerning how motivating Racing Academy was to play (See Table 5). Students in all the courses found Racing Academy enjoyable to play. Students at Penwith, Barnfield (IMI Nationals & BTECH) and Bath (Solid Mechanics) felt they were competent at playing Racing Academy. Students at Penwith, Barnfield (IMI Nationals) and Bath (Solid Mechanics) felt that playing Racing Academy was worth the effort. Students at Penwith and Barnfield (IMI Nationals) course thought that Racing Academy was a valuable exercise.

Table 4. Pre and post-test measures of motivation for engineering and physics

	Enjoyment		Importance to self		Perceived Competence	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
BarnfieldIMI Nationals	6.4	6.1	6.0	5.9	5.3	5.1
Barnfield BTECH	5.4	5.3	5.5	5.3	4.6	4.5
Bath Solid mechanics	5.2	5.1	5.0	5.0	5.6	5.6
Bath Vehicle Dynamics	5.1	5.1	5.2	5.0	4.4	4.2
Penwith AS/A2 Level Physics	5.3	5.4	4.9	5.0	4.1	4.0

Table 5. Racing academy and motivation

	Enjoyment		Competence		Effort		Value	
	M	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**
Barnfield IMI Nationals	5.2	0.6	5.2	0.6	4.6	0.8	4.7	0.7
Barnfield BTECH	4.5	1.2	4.6	0.7	3.9	1.2	4.1	1.1
Bath Solid mechanics	4.4	0.5	4.2	0.6	4.1	0.7	4.1	0.6
Bath Vehicle Dynamics	4.5	0.7	4.2	0.6	3.7	0.7	4.6	0.7
Penwith AS/A2 Level Physics	5.2	0.7	4.8	0.7	4.6	0.5	4.6	0.5

Another measure of the impact of Racing Academy on students learning is how successful they felt Racing Academy was in supporting their learning. We assessed this by asking the students the following question ‘Racing Academy was specifically designed to support your learning on your course. Do you think it was successful? Table 6 shows that ninety five percent of students thought it was successful at supporting their learning.

The students where also asked to explain why they thought Racing Academy was successful or not. Table 7 shows that 103 students said something positive, 73 said something negative, while 17 had either neutral comments or suggestions.

The comments were grouped into positive, negative and neutral comments. Table 7 shows that 76% of the students made a positive comment about the success of Racing Academy.

Example 1: “It explains scientific methods in an easier form, it is fun and enjoyable and it allows you to see the changes your making and the effects” (Barnfield IMI Nationals Student).

Example 1 illustrates a number of reasons given by students for why Racing Academy was successful. Fifty percent of students said that it increased their understanding. In Example 1, it increased the student’s understanding of the scientific method. Seventeen percent of students, like the student above, thought that the learning by doing method was an effective teaching method and thought Racing Academy was fun (10%).

Example 2: “Because I was using graphs on my performance, it helped to understand how to get better performance out of the car and this was by using the physics in the graphs to improve, so this benefitted me with my physics” (Penwith AS/A2 student).

Ten percent of students commented on the usefulness of the graphs generated by the game and how the graphs helped their learning (See Example 2).

Table 7 shows less than 50% of the students made a negative comment. Fifteen percent of students’ felt Racing Academy was not successful because it did not provide sufficient information about how to improve the car’s performance (See Example 3).

Example 3: “It had some relevance to the course, however it did not help with improving my mechanics. There was very little theory as such” (Bath Solid Mechanics Student).

Table 6. Perceived success of Racing Academy

	Percentage Number of Students			
	Not at all successful	A little bit successful	Quite successful	Very successful
Barnfield IMI Nationals	0.0	35.7	64.3	0.0
BarnfieldBTECH	11.1	44.4	38.9	5.6
Bath Soli mechanics	5.4	48.3	44.9	1.4
Bath Vehile Dynamics	6.7	26.7	53.3	13.3
Penwith A/A2 Level Physics	0.0	30.8	53.8	15.4
Overall	4.6	37.2	51.0	7.1

Table 7. Positive and negative comments

	Positive		Negative		Neutral	
	N	%	N	%	N	%
Barnfield IMI Nationals	10/14	71.4%	7/14	50.0%	1/15	7.1%
BarnfieldBTECH	16/18	88.9%	7/18	38.9%	2/18	11.1%
Bath Soli mechanics	103/140	73.6%	73/140	52.1%	17/140	12.1%
Bath Vehile Dynamics	11/15	73.3%	2/15	13.3%	10/15	66.7%
Penwith A/A2 Level Physics	12/13	92.3%	8/13	61.5%	2/13	15.4%
Overall	152/199	76.0%	97/199	48.5%	32/199	16.0%

Fifteen percent of student felt that it was not relevant to their courses (See Example 4).

Example 4: "Didn't learn anything from it, the whole process was trial and error for getting the fastest time down the track. Had no relation to what we are doing in the courses" (Bath Solid Mechanics Student).

Fourteen percent of students thought that the learning by doing method was not as effective as more traditional methods (See Example 5).

Example 5: "Some bits, like looking at the graph, were helpful, but on the whole I think I learn better from the board and listening" (Penwith AS/A2 student).

In summary, we found that most students found Racing Academy motivating and they did learn from their experience with Racing Academy. The vast majority of students thought Racing Academy was successful. When asked why? The reasons given were as follows; (1) it increased their understanding, (2) they thought learning by doing was effective method of teaching, (3) it was fun, and (4) they thought the graphs generated by Racing Academy were useful for their learning. A minority of students felt Racing Academy was not successful. The reasons they gave was because (1) a lack of information concerning how to improve the car's performance, (2) it was not relevant to the course and (3) felt traditional methods were a more efficient method of teaching.

LESSONS LEARNED

One important lesson we learnt from this project was the importance of involving both lecturers and students in the design process. Even though Racing Academy had been used before to support younger children's learning it became quickly apparent in the initial design workshops that the software required certain modifications which led to the development of the software which was more suited to the needs of the lecturers and further and higher education students. For example, it was quickly apparent that the students were using different computers and not the same computer as initially assumed, thus it was important that they had a simple way to move their design from one machine to the next. The designers quickly came up with racing car design file which stored all the design information and could be transferred from one machine to the next.

The findings from the evaluation also revealed a number of important lessons for the use of digital games for supporting learning. The first is that it is important to make sure that the game content is closely couple to the curriculum content of the course. It was apparent from the open ended comments that Racing Academy was more closely coupled to the engineering courses than the physics course. Even the representation of the car was not appropriate for the curriculum content of the AS/A2 physics course. The representation of the car in Racing Academy is a realistic representation, whereas in the AS/A2 physics course they use a point to represent the motion of an object.

The second lesson is that it is important to provide some material at the appropriate level which provides information concerning how to improve the performance of the car. The aim at the outset was for the students to search for this information online, but this proofed difficult for most of the students. The problem with providing appropriate information is that each course would require different information which would be costly to produce and maintain. One possible solution would be to set up a game website where the players of the game and lecturers who use the game can provide useful information for other players and lecturers.

A third lesson concerned the best ways to organise teams. The competition was judged on the basis of the quickest car in the team, which meant that if one member had a very quick car the other members of the team did not have to develop their own car. A more pedagogically effective organisation which would have probably led to more constructive collaboration between team members would have been to have judged the team either on the basis of their average race times or the time of the slowest member of the team. The latter may have been better because it might have resulted in the more able members supporting and giving instructions to the less able members of the team.

A fourth lesson was the overly fierce competition between the teams, which was not conducive to a more collaborative atmosphere. The competition at the end of Racing Academy may have been responsible for this overly fierce competition between some teams, which led to some students stealing over teams designs. One possible solution would be to have arranged awards based on the team's performance rather than the team's position. For example if you were awarded prizes for reaching set performance goals. For example achieving certain times (e.g. for going under 11 seconds) and/or for consistency (going under 12 second in 3 drag races in a row).

The above lesson is related to next, which concerns the individuals' motivation to play the game. Once the students had beaten the AI driver and they felt they could not compete against some of the best students they lacked motivation to carry on playing. Again one possible solution would be to have more rewards in the game. The students could be awarded medals, or laurel leaves, which may be more appropriate for a racing car game, for achieving performance goals.

Another issue was the limited use of the online forums, especially the student forums. This was particularly the case for students who saw each other regularly face to face, although the forums were used significantly more in Penwith, which was because the lecturer was a frequent contributor to the forums and responded quickly to the students' questions and comments.

A final issue concerns gender. Some students commented that Racing Academy may not be as motivating for females as Males. We have compared males and females playing Racing Academy and found that there was no gender difference in the beneficial effect of Racing Academy. In fact, there was some evidence that, female students found Racing Academy more motivating than male students (Joiner et al., 2011).

CONCLUSION

Therefore in summary, Racing Academy was successfully implemented in five courses, in two further education colleges and one university, to support the learning of physics and engineering. We found evidence that students found playing Racing Academy motivating and that it did support students' learning. The majority of students thought Racing Academy was successful because playing Racing Academy increased their understanding, (2) learning by doing was effective method of teaching, (3) it was fun, and (4) the graphs generated by Racing Academy were useful. A minority of students felt Racing Academy was not successful. The reasons they were because (1) there was a lack of information concerning how to improve the car's performance, (2) it was not relevant to the course and (3) felt traditional methods were a more efficient method of teaching. From these findings a number of lessons were discussed. These findings are consistent with previous research which has also found that playing digital games can facilitate students learning in STEM subjects in higher education (Coller, & Scott, 2009). It extends this research by showing that it can also facilitate learning in STEM subjects in further education, although the findings also show that these benefits are not universal with some students feeling it was not successful. Some of these difficulties could be overcome by providing more background material and explaining the relevance of playing the game for their course. In conclusion, this case study shows the potential of digital games for supporting students learning in STEM subjects.

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