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# Game-Based Learning in Engineering Education

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**Abstract**

The new generation of undergraduates entering UK higher education have grown up with computer games of ever increasing sophistication. In this educational project a race game, Racing Academy, was developed to investigate how game technology and gaming communities could enhance undergraduate engineering education.

The computer game embodied the principles of engineering dynamics to simulate and display in real time a car drag race in which students 'designed' their car by selecting an engine, tyres and gearbox from a set menu. The aim was to complete a set course in the minimum time and graphically display the dynamic performance in order to better understand the engineering system.

The students and staff involved in this project provided extensive feedback on the exercise and identified the visual nature of game-based learning software as a positive feature that helped illustrate engineering dynamics. Game-based learning communities, organised around tutor groups, were seen as an excellent way of encouraging an element of competition in a small non-threatening environment while discussion forums based around Moodle provided efficient support for the large group of 160 students. Finally, learning through 'doing' in a game environment was proven to be a successful method of illustrating physical phenomena.

**Keywords**: Game-based learning, Racing Academy, Vehicle Dynamics, Learning communities

## 1. Introduction

Traditional engineering degrees have been designed to satisfy UK SPEC (2004) [1] and, as such, are required to cover elements of:

- Science and Maths
- Engineering Analysis
- Design
- Economic, Social and Environmental Context
- Engineering Practice.

Ideally a range of different delivery strategies and assessment methods should be used at the various levels (C, I, H and M) in order to satisfy the requirements of accreditation and, by and large, accredited degree courses in the UK are well respected internationally. However, it is not uncommon for engineering degrees to be perceived as 'an unexciting hard slog' [2] and any teaching developments that build upon the changing prior knowledge of university students should be considered as positive enhancements to the teaching portfolio.

There recently has been considerable interest in the use of computer games in supporting students learning [3]. James Paul Gee [4] argues that computer games are 'little learning engines' that are carefully designed to be learnt through practice and active play and that 'affinity groups' of players with common interests in specific titles or genres coalesce informally around these. It is through social interaction and the use of material artefacts that members of the group access knowledge about the games, series of games or genres. Thus computer games can be seen as a dynamic social learning system [5].

In the last few years a significant change has taken place in school leavers. It is not uncommon for school leavers to have very high levels of computer gaming skills and to have significant experience in the use of computers and software as a tool for analysis, entertainment and communication. While virtual learning environments have been widely adopted to support teaching, the use of computer gaming as a teaching tool is still in its infancy.

## 2. Project Aims

The principal aim of the project was to assess the efficiency and effectiveness of a game-based learning community designed to support undergraduate students' learning. The project also had the following aims;

i. To use games to support students' learning and thus provide detailed guidance on how to use this approach across disciplines.
ii. To evaluate the effectiveness of game-based learning communities.
iii. To develop expertise in using game simulations for supporting the personal tutoring system and supporting students' learning.
iv. To develop a version of Racing Academy [6] specifically designed to support engineering students.
v. To develop learning material for Racing Academy in order to support undergraduate Mechanical Engineering students' learning of vehicle dynamics.

## 3. Racing Academy

The learning objectives of the Racing Academy exercise were as follows:

- To understand the fundamental principles of dynamics as applied in an engineering context.
- To develop judgement in system design and modelling.
- To use computer gaming software in an engineering context.
- To work independently and as a team in a competitive environment.

In order to support these learning objectives, Racing Academy uses a powerful physics engine to embody the principles of engineering dynamics to simulate and display in real time a drag race. In this race, students were able to 'design' their car by selecting an engine, tyres and gearbox ratios from a set menu.  Figure 1 shows a screen shot from racing Academy during the drag race.


Figure 1: Racing Academy Screen During Race

### 3.1 Engine Selection

Eight engine characteristics are available to the 'vehicle designer' that can be viewed graphically as a torque versus speed graph, fig. 2. In order to select the optimum characteristic for peak acceleration performance the student was required to recognise the importance of peak power versus driveability. The ideal engine in this context was a powerful engine with a flat torque delivery over a wide speed range.

Figure 2. Engine Selection Screen

## 3.2 Tyre Selection

A range of four tyre types was available and students were able to make their selection based upon the friction versus slip ratio characteristic, fig. 3. It is not surprising that the slick racing tyre was most suitable for this application although the graphical characteristics enabled the user to understand their choice.

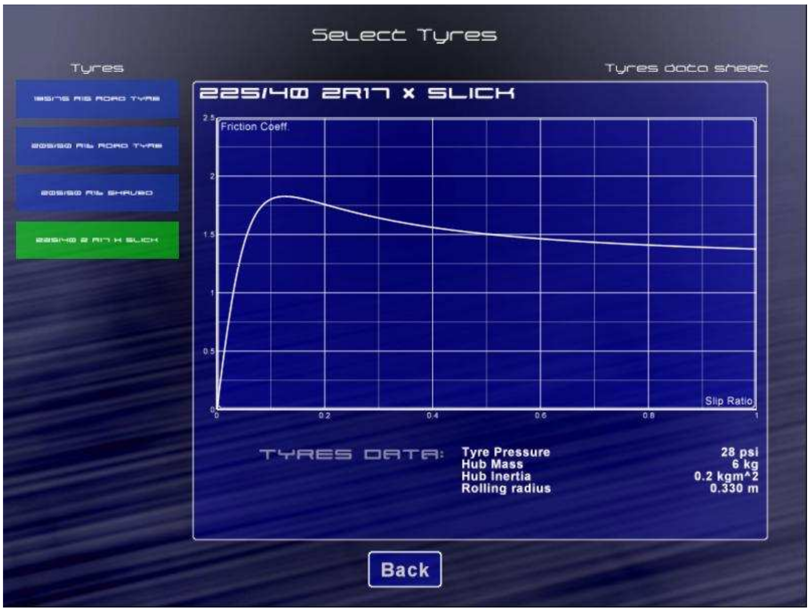


Figure 3. Tyre Selection Screen

## 3.3 Gear Ratios

Having selected the engine and tyres the game requires the user to select gear ratios for the sprint race over a quarter-mile. The software illustrates the wheel torque as a function of wheel speed for the changing ratios and enables the gear box to be designed for optimum torque delivery across the full range of the race (fig. 4). The challenge is to choose ratios that prevent wheel spin, maximise wheel torque and minimise time wasted during gear changes.

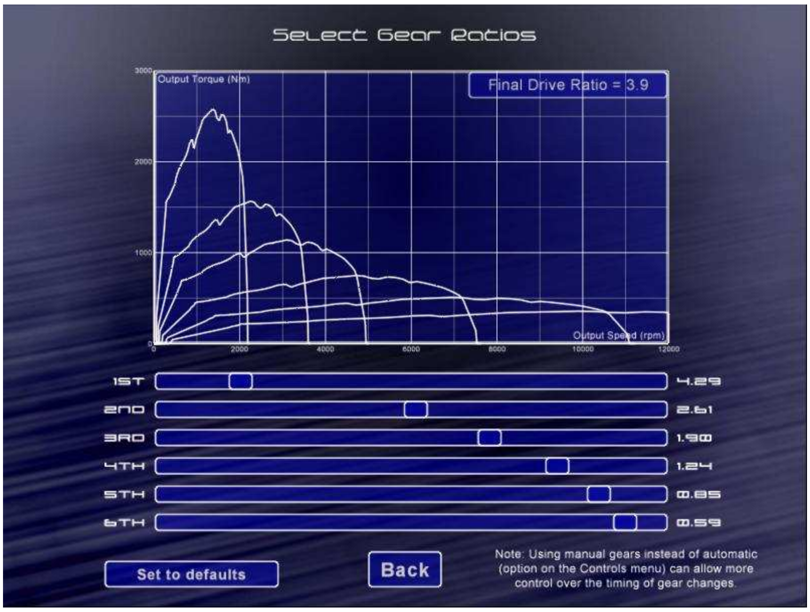


Figure 4. Gear Ratio Selection Screen

## 3.4 The Race

Racing Academy has three stages that require the user to race and win against a software rival in order to progress. The first stage requires the selection of the engine, the second stage the selection of the tyres and the third the gearbox design. In order to illustrate the engineering dynamics taking place, the user can produce a host of different graphical output, including acceleration against time and speed against time (figures 5a and 5b). These figures demonstrate the influence of wheel slip, engine torque, gear change and drag on vehicle acceleration so that design changes can be made in order to improve performance. In this way the user is encouraged to understand the engineering dynamics and use an iterative design process to optimise their vehicle. While user skill is an important aspect of the computer game the controls are very simple, enabling even the academic staff to involve themselves in the learning process!

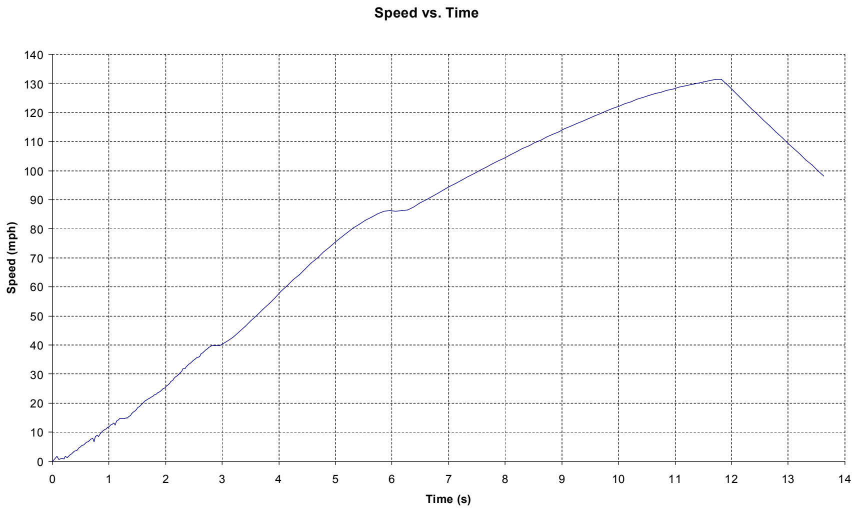


Figure 5a. Vehicle Speed

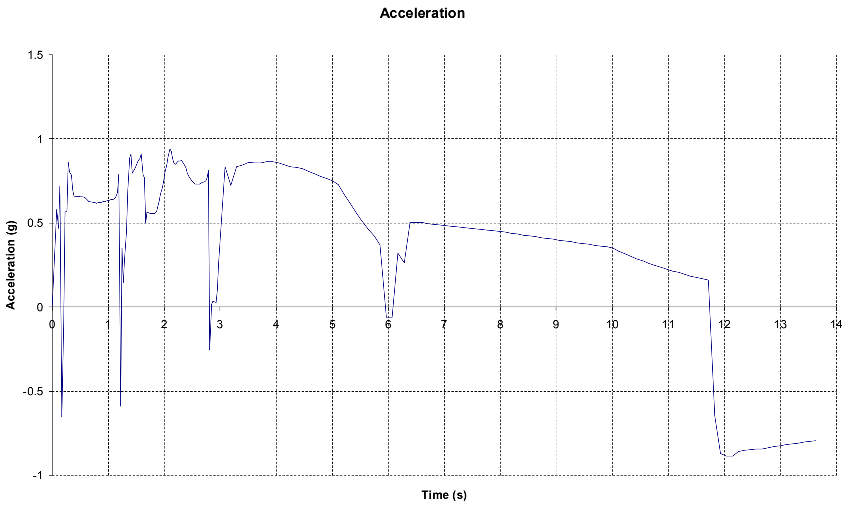


Figure 5b. Vehicle Acceleration

## 4. The Pilot Study

The drag race activity was launched in October 2006 to a class of 161 (146 males and 15 females) and ran over a three week period. A laboratory work sheet was issued that led the student through the design process both individually and then, as part of their racing team made up of their tutor group (3 to 5 students). Each team had their own discussion forum on Moodle that was overseen by their tutor and each team met formally once per week to discuss progress. The tutor was encouraged to provide guidance throughout the process and, since the activity ran at the start of the academic year, it formed a focus for tutor group discussions and helped promote interaction between individuals in the group. This fits in well with the socialisation stage of the Salmon 5-step model and encourages information exchange and knowledge construction [7]. Further support was provided by an open discussion forum on Moodle that enabled students to exchange their experiences and also for a postgraduate employed on the grant to help with engineering and software queries. Each tutor group selected their ‘champion’ to compete in a Mechanical Engineering race to identify the fastest car and driver. The race was held during a lunchtime period and the winning tutor group was awarded a substantial prize.

Following the race the students were required to write a laboratory report based upon the laboratory exercise work sheet, the software graphical output and their experience of the race. In this report they were encouraged to reflect upon the performance of their vehicle and make recommendations as to how the performance might have been improved.

## 5. Pilot Study Assessment

Racing Academy was evaluated with a pre-test which was administered a week before the project started and a post-test which was administered a week after the project had finished.

The pre and post-tests were identical and the engineering post test is presented in the appendix. These tests were designed to assess the students' prior knowledge of engineering, their attitudes towards engineering and their attitudes towards computer games. The post-test also included a measure of how motivating Racing Academy was in the context of the laboratory project. The students were also asked to keep a learning diary and two focus groups were held after the project had finished.

The findings were very interesting and the quantitative measures provided support that Racing Academy facilitated students' learning. The principal findings relating to the experience were as follows.

1. The visual nature of game-based software is very helpful in demonstrating engineering dynamics.
2. The students were comfortable with and enthusiastic about using game-based software as a teaching tool.
3. Game-based learning communities organised around tutor groups are an excellent way of improving teaching efficiency and encouraging an element of competition in a small, non-threatening environment.
4. Discussion forums based around Moodle that support both the software and technical aspects of the design challenge are a good way of dealing with large group teaching, so long as they are well supported by the teaching staff.
5. Learning through 'doing' in a game environment seems to be a successful method of illustrating physical phenomena.
6. Game-based learning within a tutor group environment, introduced at an early stage in the academic year, is a good way of breaking down barriers and improving staff/student relations.
7. It was not clear whether older students would have been similarly motivated by gaming as a teaching tool.

The detailed analysis of the pre and post test data was as follows.

### 5.1 Learning

The engineering tests were divided up into four sections which were as follows

i. general physics
ii. engines

iii. tyres

iv. gears

Table 1 shows the pre-test and post-test scores for students after they had used Racing Academy

| | Pre-test | | Post-test | | | |
|---|---|---|---|---|---|---|
| | Mean | Standard Deviation | Mean | Standard Deviation | t (df =136) | |
| General | 3.6 | 0.8 | 3.7 | 0.8 | 2.4 | * |
| Engine | 1.3 | 0.8 | 1.8 | 0.8 | 5.5 | * |
| Tyre | 1.2 | 0.9 | 1.8 | 1.0 | 7.2 | * |
| Gears | 1.6 | 1.1 | 2.0 | 1.1 | 4.4 | * |
| Total | 7.7 | 2.5 | 9.2 | 2.8 | 9.2 | * |

* $p < 0.05$

Table 1: Pre and Post-test Engineering results

The students significantly improved in all 4 areas assessed (see table 1). Overall their total score rose from 7.7 to 9.2 after playing with Racing Academy, an increase of 19%. Unfortunately it was not possible to study a control group as this project was integrated within the academic curriculum and it was felt to be inappropriate to exclude students from taking part.

5.2 Motivation

Following the Racing Academy Exercise the students were given questionnaires that assessed how motivated they were by using Racing Academy. It was found that:

- 81% of the students thought Racing Academy was enjoyable (one group t-test, t = 8.3, df =136, p < 0.05)
- 69% of the students thought they were competent at using Racing Academy (one group t-test, t = 3.4, df =136, p < 0.05)
- 66% of the students put a lot of effort into playing Racing Academy
- (one group t-test, t = 2.7, df =136, p < 0.05)
- 64% of the students thought that Racing Academy was a valuable activity (one group t-test, t = 1.9, df =136, p = 0.06)

5.3 Success

Table 2 shows a breakdown of how successful the students thought Racing Academy was at supporting their learning:

Table 2: Racing Academy Success

| How successful | No of students | Percentage |
|---|---|---|
| Not at all | 8 | 5.4 |
| A little bit | 71 | 48.0 |
| Quite | 66 | 44.6 |
| Very | 2 | 1.4 |
| Null | 1 | 0.7 |

Ninety five percent of students thought the implementation of Racing Academy was either a little bit successful or quite successful.

5.4 Open Ended Questions

Of the 140 students who answered the question concerning why they thought implementing Racing Academy was successful or not, 103 students said something positive, 73 said something negative, while 17 had either neutral comments or suggestions.

One hundred and thirty five students answered question 2, about whether they had any problems using Racing Academy, but out of 140 students, 91 had something positive to say for this question, 45 had something negative to say and 3 had neutral comments or suggestions.

47 students had a response for question 3, which asked them whether they would like to add anything else. Out of 140 students, 11 made positive comments, 18 made negative comments and 31 made neutral comments or suggestions for improvement.

In addition, the academic staff who acted as tutors to the first year students were very positive about the exercise, citing improved interaction between their tutees and an obvious enjoyment of the game-based learning activity.

## 6. Conclusions

The general outcomes of this trial were undoubtedly positive. The Learning Outcomes were met in terms of both engineering knowledge and transferable skills and the portfolio of teaching and assessment methods as required by UK Spec (2004) was widened.

Pre and post-tests that assessed engineering knowledge, motivation and success demonstrated a positive response to Racing Academy both from the students and academic staff point of view.

In conclusion, game technology and gaming communities appear to be a viable and fruitful means of both motivating students and enhancing their knowledge and understanding of engineering systems. Theoretically this paper is interesting because it is one of the first papers to show a positive learning outcome in a completely naturalistic context.

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## Appendix

### Racing Academy Pre-Lab Engineering Questions

### General Questions

1. How does the mass of a car affect its acceleration?

2. How does the mass of a car affect wheelspin?

3. Name three factors that influence the top speed of a vehicle?

### Engine Questions

1. A Chevrolet Matiz has a 1 litre engine that produces 48 kW. A Yamaha R1 also has a 1 litre engine that produces 129 kW. Both engines have similar maximum torque figures (approximately 100 Nm) and use the same fuel. How can the Yamaha produce over two and a half times the power?

2. Why is it important for heavy truck engines to produce large amounts of torque? What does torque provide?

3. Why is it important for Formula 1 engines to produce large amounts of power? What does power enable the car to do?

**Tyre Questions**

1. Is it possible for a tyre to have a coefficient of friction greater that 1?

2. Why are slick tyres not fitted to road cars?

3. How does tyre compound affect grip? Do road cars have soft or hard tyres? Why?

**Gearbox Questions**

1. Why do cars have gears?

2. Cars with an automatic transmission often have a ‘kickdown’ function where the gearbox automatically changes down a gear when are large acceleration is required (such as when overtaking). Why does this help?

3. How does gearbox spacing affect the performance of a car? Why do some vehicles have a close ratio gearbox whereas other vehicles have gear ratios far apart?