Abstract
“Positive student effect: confidence increased, students enjoyed themselves and want to learn more about special relativity”.

These words at the beginning of the research report indicated a positive learning experience had taken place for both internal and external students studying special relativity.

A computer program, Real Time Relativity, developed at the Australian National University, by Lachlan McCalman, Antony Searle, Craig Savage and Michael Williamson, was given to students studying Special Relativity at Murdoch University in Western Australia. The students were asked to “play the game” and the effectiveness of their play was judged with pre and post game surveys. Comments and lab notes showed that their understanding of the scale and effects of special relativity deepened as they developed their own visual models. It also appears that the game experience worked as well for students studying by correspondence, as it did for on-campus students.

Introduction
The computer program “Real Time Relativity” (RTR) (McCalman, Searle et al.) is a game-like computer simulation in which the game-universe is seen from the point of view of a person in a space ship. The space ship can move at relativistic speeds around and through three dimensional objects enabling students to visualize otherwise abstract concepts. It effectively demonstrates length contraction, time dilation, Doppler shift and the relativity of simultaneity (Savage, Searle et al. 2007). The program has previously been used successfully by on-campus students at The Australian National University (ANU) and The University of Queensland (UQ). In this study it was being tested by on-campus and correspondence students at Murdoch University in Western Australia.

Murdoch University has offered a correspondence physics degree since its inception nearly 35 years ago and has strived to maintain a hands-on laboratory approach to the degree. In order to do this each correspondence student is sent an experimental kit of equipment. The kit allows the students to do the Frank-Hertz experiment, study spectra and investigate Planck’s constant. There is also data for the photoelectric effect and the study of the emission spectra of tungsten. This data is displayed using the software accompanying the Vernier Spectrometer on which the data was collected. In other words, the kit contained a CD with plenty of room to add the RTR software.

As well as sending the RTR software to the correspondence students it was installed on the on-campus laboratory computers and burnt to a couple of extra disks. All students, internal and correspondence, were therefore able to have a similar learning experience. In fact it turned out to be even closer than we expected. The internal students opted to take a copy of the software home so they could spend more time working with the game.

Experiment
The session with the RTR software was treated as an ordinary laboratory session. All students should have had the lectures before doing the lab but would not have done the relevant assignment. For lectures the external students access an audio recording which accompanies a PowerPoint presentation on the unit website.

In the lab session students were asked to do the following in the given order
• a pre-experiment survey which assessed their confidence in dealing with special relativity
• a pre-test to assess their understanding of the concepts
• work through the lab guide as given to students at ANU while playing with the software
• a concepts post-test
• a post-experiment survey on their confidence in dealing with special relativity concepts

The students were given full marks for just attempting this lab so there was no reason for them to try and do anything other than what they were asked, or for them to do it in any other way. The results are therefore a good indication of the reality of the situation.

It is important to note here the small sample size involved in this research i.e. five on-campus students and four correspondence students. Murdoch University is a small university when compared to other universities such as ANU and UQ and the number of physics students are therefore proportionately less than at the larger universities.
Results
Q1. What was the most interesting thing that you learned from this experiment, and how did you learn it?
Students generally commented on gaining a visual understanding:
- “It was helpful to cement the ideas and to give me a more visual understanding of them”
- “Seeing it occur reinforced the concepts well and I now feel like I have a better understanding”

Most students identified optical effects particularly aberration as the most interesting aspect:
- “The most interesting effect I found was the way light from behind curved around, so it looked like it was coming from infront, when moving at high speeds.”
- “The most interesting thing was the aberration (it) caused objects to appear differently and when navigating would sometimes cause it to appear that you were further back or forward then you were depending on if you were going backwards or forwards.”
- “The most interesting thing I ‘learned’ from this experiment was the way that objects change shape at near light speeds”
- “That when travelling at near-light velocities, objects can appear to curl around you.”

Q2. What aspect of this experiment most needs improvement?
Some correspondence students had issues with the RTR interface i.e. dark graphics and keyboard navigation. This could have been a function of their computer equipment as much as the software. Still it is worth looking for opportunities for improvement.

Q3. Please provide any additional comments on this experiment here.
Recommended improvements:
- “To be able to observe the space ship from a stationary pos. so you can observe length contraction or the flashing light example in post test q1.”
- “Observing the spacecraft moving from another inertial reference frame would also be useful to have”
- “There could be more interaction between a student and this program. e.g. a student could be asked to complete tasks within the program where the effects of relativity can alter the outcome of such a task.”

Commendations:
- “This program did help me realise the size of the effects of relativity.”
- “I really enjoyed playing RTR”
- “A good experiment, although I don’t feel that 2 hours are needed to complete it.”
- “Overall very good way to teach people about the topic in a way which encourages the user to investigate for themselves how it all works, which is the best way to learn.”

Other:
- “It’s all good letting students investigate for themselves but what if they still don’t get it?”
- “It’s a real pain to get running at home.”

Differences between on-campus and correspondence students
The two cohorts placed slightly different emphasis on what they considered needed improving with the experience. The external students were more focused on the technological aspects i.e. the darkness of the screen and the navigation using the keyboard while the on-campus students would have liked more explanation of the visual effects and how they link to the mathematics behind the effect. There did not appear to be any noticeable difference between the two groups in the learning that was taking place or the increase in the level of confidence of the students in dealing with relativistic concepts.

Conclusions
The Real Time Relativity lab will become part of the Murdoch University Modern Physics unit from here on. We may modify the accompanying written materials to make them complement the rest of our laboratory sessions and will feed the changes back to the original authors. The software was successful in assisting on-campus and correspondence students to visualise the effects of moving at relativistic speeds and in so doing enhanced their confidence in their own understanding of the concepts. Lastly, but by no means the least consideration, playing the game was fun!

References