

Einstein-First: Researching the benefits and feasibility of revising school science with early introduction of Einsteinian physics.

Postdoctoral and Postgraduate Research Opportunities in Physics Education

The following positions are currently available and will remain open until filled. Those interested should contact david.blair@uwa.edu.au.

Research Associate: Post-doctoral research opportunity

The Einstein-First research project is a collaboration between The Gravity Discovery Centre, The Graham (Polly) Farmer Foundation, and three universities in Perth: University of Western Australia, Curtin University and Edith Cowan University. It is closely linked to UWA's participation in the LIGO Scientific Collaboration through the Education and Public Outreach Working Group.

We are seeking expressions of interest from suitably qualified applicants interested in part time or full time employment as a research associate in the Einstein-First Project, which is described below. The project involves a) development and trialing of curriculum materials in schools (years 7-12) aimed at students from all backgrounds including indigenous students, b) data collection and analysis and preparation of draft papers for publication, and c) conducting and evaluating teacher professional development. The research associate would offer day to day leadership and coordination of a growing team including PhD and MSc students, while working closely with physicists and educationalist at UWA and Curtin, and members of the collaborating institutions. For information on the background of this project see the article below.

Applicants should have a passion for physics education, and excellent conceptual knowledge of quantum mechanics and special and general relativity, and willingness to obtain special training in indigenous education. They should have knowledge and experience with data collection and analysis, have demonstrated classroom skills and competency in preparing curriculum materials and preparing papers for publication.

Essential Selection Criteria

1. PhD in physics or other relevant field,
2. Diploma of Education or equivalent and/or teaching experience,
3. Education research experience,
4. Experience with and/or willingness to train to work with aboriginal students,
5. Working with children card,
6. Excellent oral and written communication skills,
7. Excellent interpersonal and team work skills,
8. Demonstrated organisational skills and capacity to work independently.

Postgraduate Research Studentships

We are offering PhD and Masters projects in the Einstein-First Project. Applicants should have suitable undergraduate qualifications in physics covering quantum mechanics and special and general relativity, excellent writing skills and interest in a school teaching career. PhD students would be trialling, testing and evaluating programs with specific target groups. We are hoping to enroll 3 PhD students in this research program. International students without an Australian Permanent Resident Visa and unable to afford Australian International Student Fees would need to win an International Postgraduate Research Scholarship, or equivalent (at one of the participating universities). These scholarships are extremely competitive and require the applicant to have one or more international peer reviewed publications.

Einstein-First: Teaching Einsteinian Physics at School

Rationale: Between 1900 and 1920 discoveries by Einstein, Planck and others revolutionised physics. Evidence of the existence of photons led to quantum mechanics and evidence that space is curved confirmed the core prediction of Einstein's general theory of relativity. These discoveries, which together we define as *Einsteinian physics* led to a completely new understanding of space, time, gravity, matter and radiation. Today Einsteinian physics has been tested to high precision, and is the fundamental basis for gravitational wave astronomy. Einsteinian physics lies at the heart of modern technology such as mobile phones, and is essential for understanding modern astronomy and timekeeping. *Despite these extraordinary developments, all based on science first conceptualised almost 100 years ago, physics in schools is still taught from a 19th Century Newtonian standpoint.*

The unfamiliar mathematical basis of general relativity, combined with conceptual difficulties of interpreting it prior to about 1960 led to a general belief that Einsteinian physics was beyond the reach of ordinary people. Thus it has been avoided in school. *We argue that we owe it to our children to teach them the modern paradigm of Einsteinian physical reality that today represents our best understanding of the universe.* Furthermore, we argue that Einsteinian physics should be taught as a "first language" and not as a second language learnt in adulthood - it is necessary to teach the modern paradigm while children are forming the world view with which they conceptualise reality.

Evidence: We have strong evidence from pilot studies that the modern paradigm can be presented accurately and quantitatively without resort to complex mathematics. Our evidence shows that the concepts of curved space, time dilation, four dimensional spacetime and quantum weirdness are seen as neither confronting nor revolutionary when taught to students young enough to have not already formed the Newtonian world view of absolute space and Euclidean geometry.

In a series of pilot studies we have been investigating the ability of students aged 11-16 to comprehend Einsteinian physics. (Pitts et al.2013). We have developed low cost curriculum materials and teaching aids that bring Einsteinian physics vividly to life. We make extensive use of activity based learning and analogies. For example we use foam bullets as analog photons and use these to teach about photography, quantum uncertainty and the photoelectric effect. We use laser pointers for beautiful simple interference experiments which are interpreted in the context of photons. We teach experimental geometry on curved spaces to show how Euclidean geometry is a special case of a more general geometry. We use lycra sheets to illustrate the concept that “matter tells space how to curve and space tells matter how to move”. We use this to investigate orbits, gravitational lensing and Newton’s law of gravitation in the Einsteinian context. More advanced students undertake calculations of gravitational light deflection, time dilation, mass-energy, radiation pressure. A key part of the program at senior levels involves making the connection between Einsteinian physics and the Newtonian approximation, which lead into classical Newtonian physics curriculum content.

Professional Development: A most important part of our program is the design of professional development training programmes for school teachers, and testing whether teachers can attain a sufficient level of confidence to teach our program.

All our results confirm the feasibility of teaching Einsteinian Physics at school. Students show a very high degree of motivation and learning. *Students overwhelming think that the material is interesting and not too complex.* In attitude assessments, we find a strong correlation between difficulty and interest: those parts of the course that are most difficult are also the most interesting.

Proposal: *We propose that the modern paradigm should be introduced to all students across the entire high school years 7 to 12 in the National Curriculum.* We need to provide professional development material to allow teachers to upgrade their skills. We have tested teacher groups and found excellent response and uptake of the new curriculum material we have developed.

Many of the programs were developed in the informal specialist learning environment of the the Gravity Discovery Centre, in conjunction with the national Youth Science Forum. Special indigenous programs have been developed with help from the Graham (Polly) Farmer Foundation’s Partnerships for Success program.

Implementing a Paradigm Shift: Historically the struggle to achieve more accurate understanding of nature involved major paradigm shifts, epitomised by the transition from the Newtonian to the Einsteinian worldview (Thagard, 1992). While physicists understand Einstein’s theory of gravity as one of the most beautiful and elegant theories ever created, everyday people’s understanding of gravity is at best Newtonian (Blair, 2012). Similarly, the concepts of quantum mechanics – photons and quantum uncertainty – which underpin our understanding of matter on the small scale, remain a mystery to most people. *Overall, our best understanding of space, time and matter is withheld from the broad public because these ideas have not*

entered mainstream education.

The subject matter of Einsteinian physics is neglected in primary and high school curricula within Australia and worldwide (e.g. ACARA, 2012). Einstein's ideas are only sometimes made accessible to students in the final years of high school or more often in university even though our results and the results of others do show that these concepts can be understood by school students (e.g. Baldy, 2007). *Nineteenth century concepts about matter, space, time and geometry are still taught in schools as if this was the way that today's scientists also understand reality.*

Pilot Studies. For our pilot studies we developed an array of low cost hands-on activities that have been tested with students from ages 11 – 16. These were reported at the World Conference on Science and Technology Education in 2013, and can be found on the Science Education Enrichment Project website.(Blair 2013, Pitts in press) We have conducted trials with different cohorts of students: a) two, seven lesson programs on gravity and quantum weirdness with mainstream Years 6, 7 and 8 classes; b) a 21 lesson program on Einsteinian physics with Year 9 gifted and talented students, and c) a one day program on curved space and quantum weirdness with Year 11 National Youth Science Forum students. We developed, trialled and improved appropriate hands-on and theoretical teaching and learning materials for each level. Moreover, for each pilot study we conducted questionnaires to test students' conceptual understanding and attitudes towards the content and teaching methods.

The results of our pilot studies have given us a high degree of confidence that this curriculum innovation is feasible and practical, that it improves student attitudes to science, and that it will give Australia an international competitive advantage in science education which will be economically advantageous to Australia. The Einstein-First project is designed to provide definitive evidence for the feasibility of widespread introduction of the new paradigm.