Review to **Achieve Educational Excellence** in Australian Schools

Public submissions for the Review to Achieve Educational Excellence in Australian Schools

Organisation: ARC Linkage Project Chief Investigators and Partner Investigators
Submitting as a: Academic person or institution
State: WA

Summary

The submission reports and positive student and teacher responses and unexpected but spectacular results for gender equalisation in knowledge and attitude to STEM topics through a modified school curriculum that gives it an Einsteinian science focus. this involves early years introduction of Einsteinian concepts regarding mathematics and geometry, mid years introduction of concepts about light and gravity and relativity of space and time. All this prepares students for later year introduction of more formal learning, and prevents the current cognitive conflict between early year teaching of obsolete 19th Century Newtonian concepts and the science that drives technology today.

It is suggested that badging Australia as being in the forefront of curriculum transformation to an Einsteinian focus would be of major national economic benefit.

Main submission

Submission to the Ministerial Review Committee on the National Curriculum

Submitted by Winthrop Professor David Blair on behalf of the Einstein-First education research project funded by the ARC Linkage program.

Partners: UWA, Curtin University, Gravity Discovery Centre Foundation

This submission was prepared by members of the Australian Research Council funded Einstein-First education research project which is focussed on the need to modernise school science by reconstructing the curriculum around modern Einsteinian science instead of the current curriculum which is almost entirely based on obsolete 19^{th} century physics. We are part of an international Einsteinian Physics Education Research (EPER) Collaboration, involving Norway, Scotland, Germany, Korea, China and Australia.

Outcomes: We have accumulated strong evidence as follows:

a) that students respond very positively to a modified *Einsteinian* curriculum and that it is feasible, inexpensive, and leads to substantial learning,

b) that it leads to substantial improvement in student attitudes to science and

c) that girls respond more strongly than boys so that the program simultaneously boosts science education across the board, *and equalises gender differences in attitude to science.*

Benefits: It is suggested that adoption of a curriculum that has been re-constructed to eliminate the cognitive conflict between a 19th century Newtonian conception of reality, taught between the ages 5-15 and the modern best understanding (learnt only by physics specialists from age 17 to tertiary) would *increase the uptake of STEM subjects*, and hence *increase Australian innovation and international competiveness.*

We want to be clear that we are *not* teaching demanding science for advanced students. We believe that everyone has the right to learn humanity's best understanding of reality (which is a world of quantum processes and Einsteinian relativity) because it underlies all the technologies that are central to our lives today: solar cells, cameras, smart phones, medical and gene technology.

Teacher Training: In many teacher professional development trials we have shown that teachers from K-12 can easily digest the key concepts that extend from primary school (arithmetic and geometry), primary and middle school (space, time, light and gravity) to high school (atoms, trajectories, orbits, and quantum processes).

Resources: Although it is not expensive, it will require resources and time to equip teachers with appropriate training. The transformation to an Einsteinian paradigm could begin as an aspirational goal and national recommendations. A trajectory for transformation could be designed. Modest funding could be made available for teacher retraining and for revision of on-line learning materials.

Marketing Australian Education: If Australia were to take up Einsteinian science it would be very valuable for the branding and marketing of the Australian education industry, demonstrating our commitment to innovation.

International aspects: Scotland's new Curriculum for Excellence has strong emphasis on Einsteinian physics, Norway and Korea have included Einsteinian physics in their national curriculum, and many others are likely to respond as research from our collaborators increases. Germany has funded a Hereaus Seminar on the topic which wil be attended by all members of the EPER collaboration.

Teaching Einsteinian Physics at School: Further Details and References

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, science in schools is founded on 19th Century Newtonian concepts which are incompatible with the modern understanding.*

The table below summarises some of the key contradictions that begin in primary school and extend through to high school.

School physics today / compared to the real world!:

- Euclidean geometry / Curved space geometry
- Absolute space and time / Relative spacetime
- Light is a wave; electrons are particles / Particle-wave duality
- Energy is massless / $E= mc^2$
- Newtonian determinism / Quantum uncertainty
- Gravity: mysterious force / Gravity: curved spacetime

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 present evidence 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 development of professional development training programmes for school teachers, and testing whether teachers can attain a sufficient level of confidence to teach our program. Results confirm that teachers are comfortable and enthusiastic about the program and would be willing to teach it given limited in-service training.

Student response: 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 all cases we observe high levels of conceptual understanding and improvement in student attitudes. Possibly the most significant result is that girls respond more positively than boys, generally equalising the gender difference. In every case where we have compared male and female outcomes we observe this surprising and important outcome in regard to gender effects. In all cases, independent of age group, academic stream and culture (including one intervention in Indonesia) we find that female enter our programmes with substantially lower attitude scores than males, while on completion their attitudes are comparable to the boys. These results are strong and of very high statistical significance.

Proposal: *We propose that the modern paradigm should be introduced to all students across the entire K-12 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. 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. 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 but this has begun to change with the formation of the EPER collaboration. 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, as shown by Baldy in 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 first reported at the World Conference on Science and Technology Education in 2013, and are detailed in the references) We have conducted trials with different cohorts of students representing a total population size greater than 500. Examples include a) two seven-lesson programmes on gravity and quantum weirdness with mainstream Years 6, 7 and 8 classes; b) two 21 lesson programmes on Einsteinian physics with Year 9 gifted and talented students, c) multiple 1-day programmes with years 6-10, c) and one day programmes 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, has a dramatic gender equalising effect, and that it will give Australia an international competitive advantage in science education which will be economically advantageous to Australia.

Public Interest: Our pilot studies appear to have caught the public imagination nationally and internationally. The Australian Chief Scientist requested an article on the research for his book The Curious Country. See link below. Numerous readers responded very positively to an article written about our pilot studies in *The Conversation* (google David Blair The Conversation viewable on-line). Multiple conferences nationally and internationally have requested talks and workshops on Einsteinian Physics Education, most recently in Dublin and Moscow.

National Benefit: It is self evident that any curriculum change that will generally improve student attitudes, increase their motivation and interest in science and incurs no severe financial penalty must be in the national interest. Educationalists across the world have recognised the need for this change. Australia will be in the forefront of this education revolution if we act now.

References:

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2. An Exploratory Study to Investigate the Impact of an Enrichment Program on Aspects of Einsteinian Physics on Year 6 Students Marina Pitts, Grady Venville, David Blair, Marjan Zadnik. Research In Science Education June 2014, Volume 44, Issue 3, pp 363–388
3. Why did the apple fall? A new model to explain Einstein's gravity Warren Stannard1, David Blair, Marjan Zadnik and Tejinder Kaur European Journal of Physics, Volume 38, Number 1 (2016)
4. Teaching Einsteinian physics at schools: part 1, models and analogies for relativity Tejinder Kaur, David Blair, John Moschilla, Warren Stannard and Marjan Zadnik Physics Education, Volume 52, Number 6 (2017)
5. Teaching Einsteinian physics at schools: part 2, models and analogies for quantum physics Tejinder Kaur, David Blair, John Moschilla and Marjan Zadnik Physics Education, Volume 52, Number 6 (2017)
6. Teaching Einsteinian physics at schools: part 3, review of research outcomes Tejinder Kaur, David Blair, John Moschilla, Warren Stannard and Marjan Zadnik Physics Education, Volume 52, Number 6 (2017)