ISSN (O): 3083-2594

AIMERS
FOUNDATION
CREATING IMPACT
- FOR ALL - BY ALL

Make A Mark

Academic Journal for Students

Creating Confident Science Communicators

Volume 1 | Issue 2 | May 2026

Published By
AIMERS Foundation

Andrew Charlton MP
MEMBER FOR PARRAMATTA

May 2026

I am pleased to write in recognition of the work being undertaken by AIMERS Foundation, an Australian technology not-for-profit, in the area of space education and international collaboration.

It is encouraging to see an Australian organisation playing a meaningful role in Mission ShakthiSAT – an all-female-led lunar space mission that is providing 120 hours of free satellite-building training to 12,000 girls across 108 countries. AIMERS Foundation has been appointed to lead the Global Fundraiser for this mission, and I note that over 140 girls from Australia are currently participating in the program.

Mission ShakthiSAT is often recognised as the world's first all-female-led lunar space mission, providing young women with hands-on experience in real satellite development. This training is offered entirely free of charge, reflecting a genuine commitment to ensuring access to space education. Australia's participation in a mission of this scale is something worth recognising.

Beyond Mission ShakthiSAT, AIMERS Foundation runs a range of programs spanning space education, robotics, youth media, academic publishing, and STEM entrepreneurship. This breadth of activity works to create meaningful pathways for young Australians, particularly those from underrepresented communities, to engage with technology and innovation.

I wish AIMERS Foundation, Mission ShakthiSAT, and all the young women involved every success with this initiative and with the Foundation's broader goals of growing Australia's technology and innovation capability.

Sincerely,

Andrew Charlton

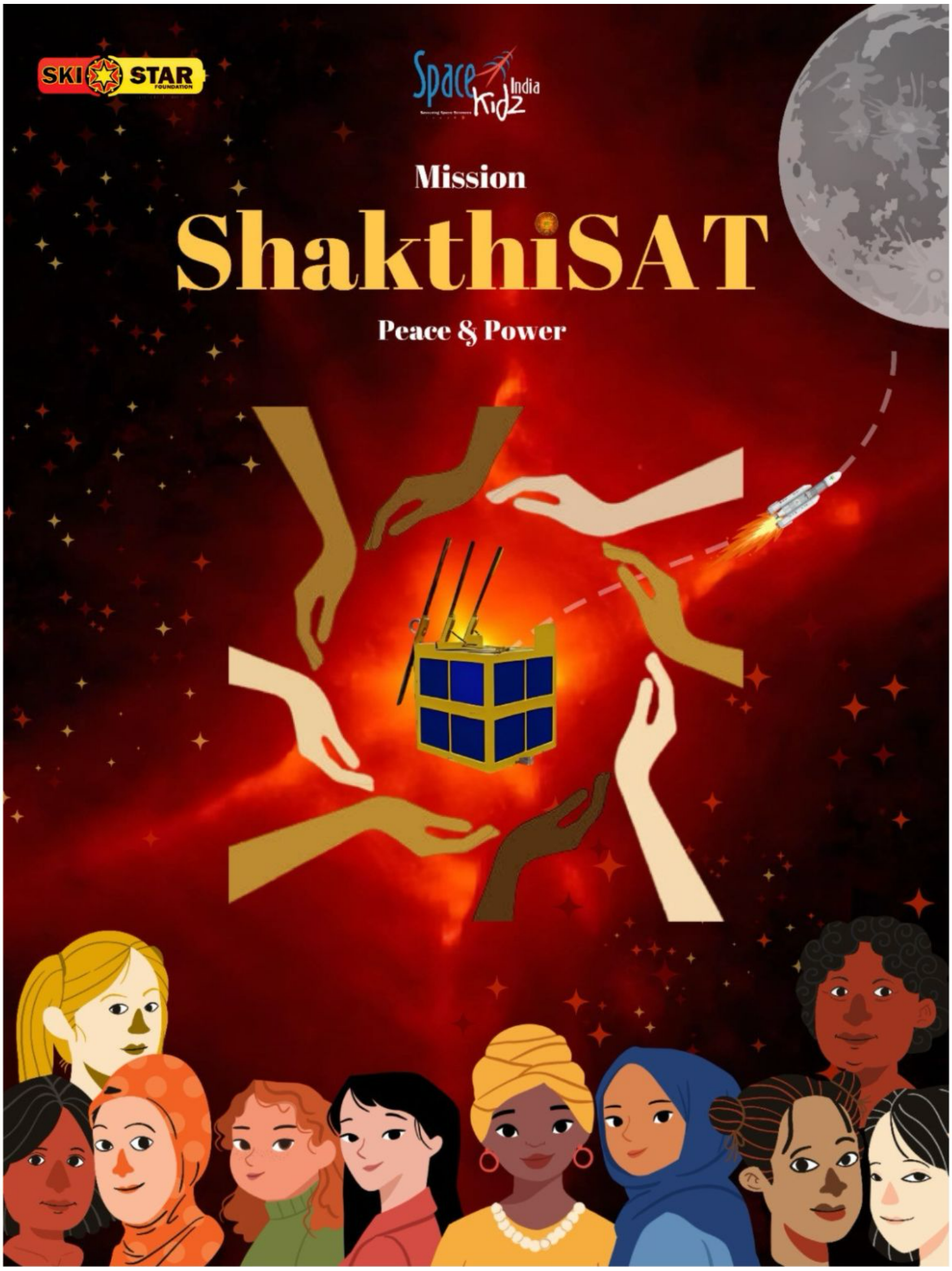
Dr Andrew Charlton MP
Cabinet Secretary
Assistant Minister for Science, Technology and the Digital Economy
Federal Member for Parramatta

1/25 Smith Street, Parramatta NSW 2150 PO Box 395, Parramatta NSW 2124
(02) 9689 1455 andrew.charlton.mp@aph.gov.au
www.andrewcharlton.com.au

AIMERS Foundation recognised at the Parliament of NSW for its body of work.

Hon. Jacqui Munro MLC – Shadow State Minister for Science & Technology passing the Parliamentary motion in Legislative Council.
https://www.youtube.com/watch?v=Rf2Oe5PJuWA

Ms. Robyn Preston, Member for Hawkesbury passing the Parliamentary motion in Legislative Assembly. https://youtu.be/2d8tmttEUfQ?si=ZYm93vorG-6Gn4sc



An all female led Lunar Space Mission Empowering 12,000 girls from 108 countries across the World with free 120 hours of training on Satellite building.

Publisher : **AIMERS Foundation**

Country of Publishing : **Australia**

Website : www.aimersfoundation.org

Email : mamjournal@aimersfoundation.org

ISSN(O): 3083-2594

Table of Contents

Make – A – Mark

Editorial

Dr. T V Gopal
Editor – In – Chief
Make – A – Mark, AIMERS Foundation &
Adjunct Professor
Department of Computer Science and Engineering
Mahindra University, Hyderabad
e-mail: gopal.tadepalli@mahindrauniversity.edu.in

1. As Open as Possible

Open science (also known as open research) is global movement to make scientific research, including publications, data, physical samples, software, and models, transparent and accessible to all levels of society through collaborative networks.

Most institutions are introspecting on any legal or ethical reasons preventing the open accessibility. Many countries are specifying the governing policies. The target for the transition to an open access publishing system by 2026 was set by the Swedish government. Netherlands has specified the Open Technology Programme 2026 for providing funding for free and unrestricted applied and technical-scientific research without disciplinary boundaries.

United Nations Educational, Scientific and Cultural Organization (UNESCO) works to accelerate the benefits reaching everyone through open science. The UNESCO Recommendation on Open Science outlines a set of actions to ensure open science for all.

Prior to the adoption of the UNESCO Recommendation in 2021, there was no universal definition of open science. Some standards existed only at the regional, national or institutional levels. In adopting the Recommendation, 194 countries have agreed to abide by common standards for open science.

The term 'open research' gained wider acceptance as a broader alternative term to "open science" by including the humanities and arts alongside traditional scientific disciplines.

2. Serials Crisis

As a matter of fact, the movement towards "Open Science" truly began in the 1990s. the journal subscription prices and the pricing of conference proceedings at that time led to what became known as the "serials crisis". The higher costs were compelling may institutions worldwide to limit the number of subscriptions to journals and purchase of conference proceedings. It therefore becomes increasingly difficult to adequately supply scholars and scientists with the scholarly information they require. There have been many solutions to resolve this crisis.

I have been associated with the ideas associated with "CSI Digest" as a collaboration between the Computer Society of India [CSI] and International Federation for Information Processing IFIP] in the early 1990s. I served as the Editor and Publisher for the CSI Digest for a couple of years.

“Occasional Papers” are often less formal than peer-reviewed journals but more comprehensive than working papers, focusing on timely, in-depth analysis. I reviewed a few during the late 1990s.

Preprint is another method I was working with during the early 2000s. Preprint is a scholarly work that has not (yet) undergone peer review. The term is sometimes also used to refer to the manuscript version of a work that is submitted for publication to a journal or a publisher.

Around a decade back, I published a few papers through the Public Knowledge Project (PKP). It is a research and development initiative within the framework of which open-source software applications for managing and publishing scholarly journals and conferences was developed.

A repository is a document server at a university or a research institution on which scholarly materials are archived and made available to the public worldwide on a long-term basis. The Registry of Open Access Repositories (ROAR) is a list of open access repositories.

MEDLARS (Medical Literature Analysis and Retrieval System) is a comprehensive, computerized bibliographic system established by the U.S. National Library of Medicine (NLM) in 1964. It was designed to store and retrieve references to biomedical journal articles, books, and technical reports. This effort is regarded as very valuable to save many lives.

All these efforts made the publishing, dissemination, stocking and accessing free and at the same time in adherence to the publishing standards and the applicable intellectual property rights. Research should not suffer from lack of access to knowledge.

Several significant trends have expanded the possibilities for publishing research as open. These trends include the emergence of several open publishing venues, author self-archiving through institutional repositories and preprint servers, and open publication mandates adopted by funders and institutions. Many regional and national governments are proactively facilitation “Open Science”.

3. Data Sharing – FAIR Principles

The FAIR principles were formally introduced in 2016 through a publication in Scientific Data. These guidelines emerged from a 2014 workshop in Leiden, Netherlands that addressed the challenges in data sharing and reuse. These principles enhance the transparency, efficiency, and impact of the research.

The FAIR Principles are:

Findability: Data and metadata should be easy to locate both by humans and machines.

Accessibility: Data should be retrievable using standardized protocols.

Interoperability: Data should be compatible with other datasets and tools.

Reusability: Data should be well-described and documented to allow for replication and further use.Young researchers are benefitting from these practices undergoing operation.

4. Global Organizations

Several key global organizations and coalitions are actively promoting Open Science. Some of the most important organizations are mentioned below.

- UNESCO (United Nations Educational, Scientific and Cultural Organization)
- International Science Council (ISC)
- Research Data Alliance (RDA)
- cOAlition S supported by the European Commission and the European Research Council (ERC)
- CODATA (Committee on Data for Science and Technology) which is an interdisciplinary body
- Global Research Initiative on Open Science (GRIOS) supported by the G7 and French National Open Science Fund
- World Bank (Open Knowledge Repository)

Open Science for students means free, immediate access to research papers, data, and educational resources, removing barriers to knowledge and allowing them to build on existing work rather than duplicating it.

Articles

The Challenges in Building a STEM Ecosystem: Is the Issue Access or Sustaining Interest?

Sukruti Narayanan
Managing Editor – Make A Mark Journals
Founder & President – AIMERS Foundation

The Emergence of STEM as a Global Educational Framework

The term STEM, representing Science, Technology, Engineering, and Mathematics, was formally introduced in 2001 by Judith Ramaley during her tenure at the National Science Foundation (NSF). Prior to this, the acronym "SMET" (Science, Mathematics, Engineering, and Technology) had been used within educational and policy discussions. The transition from SMET to STEM was not merely linguistic; it reflected a broader attempt to create a more accessible and unified framework for discussing scientific and technological capability development.

Although the term itself is relatively recent, the philosophical foundations of STEM education emerged decades earlier. Following the launch of Sputnik by the Soviet Union in 1957, many nations intensified investments in science and mathematics education as a matter of economic competitiveness, technological advancement, and national security. Over time, STEM evolved into a global policy framework connecting education, workforce development, innovation, research, and economic growth.

STEM as National Strategy and Educational Transformation

By the early 2000s, governments across countries including Australia, United Kingdom, South Korea, China, and United States had begun embedding STEM within national education strategies. In Australia, this led to initiatives such as the National STEM School Education Strategy 2016–2026, which emphasized interdisciplinary learning, innovation capability, and workforce preparedness.

The rise of STEM also transformed educational philosophy. Rather than teaching scientific disciplines in isolation, schools and institutions increasingly adopted integrated and project-based approaches involving robotics, coding, engineering challenges, design thinking, artificial intelligence, and real-world problem solving. STEM became more than a collection of subjects; it emerged as a method of inquiry and innovation-oriented learning.

At the same time, STEM gained remarkable visibility as a public narrative. Governments, universities, industries, and nonprofit organizations positioned STEM as central to employability, entrepreneurship, technological leadership, and national development. By the 2010s, STEM had become deeply embedded within policy language, workforce planning, scholarships, public campaigns, and educational reform agendas.

The Rise of STEAM and the Debate Around STEM

However, the global expansion of STEM has also generated significant debate. Critics have argued that STEM frameworks can become overly tied to labour-market outcomes, reducing education to economic utility rather than holistic human development. Others have highlighted that creativity, ethics, communication, journalism, and the humanities are often marginalized within highly technical approaches to education.

This criticism contributed to the emergence of STEAM, which integrates the Arts into STEM in recognition that innovation also depends on storytelling, ethics, culture, design, and public communication.

Importantly, STEM has also evolved into a movement for inclusion and representation. Governments and organizations increasingly recognize the importance of improving participation among women and girls, Indigenous communities, migrants, regional learners, and historically underrepresented groups. The expansion of STEM equity initiatives reflects growing understanding that innovation ecosystems become stronger when participation is diverse and socially inclusive.

Access Versus Sustained Engagement: The Central Policy Question

Despite these developments, an important policy question remains unresolved: is the primary challenge in STEM ecosystems truly about access, or is it about sustaining long-term engagement?

Globally, including within Australia, many STEM engagement strategies continue to operate under the assumption that exposure automatically creates aspiration. Workshops, science fairs, coding camps, robotics competitions, and innovation festivals often generate immediate excitement. Yet temporary enthusiasm does not necessarily translate into sustained participation, long-term learning pathways, or future careers in science and technology.

In many cases, students experience a short-term “wow moment” but not a long-term developmental journey. After participating in a STEM event, many young people return to environments where there is limited mentorship, no clear progression pathway, minimal peer reinforcement, and little connection between their experiences and future identity. As a result, interest gradually diminishes.

This distinction has become increasingly important within educational policy discussions. There is now growing recognition of the difference between STEM activation and STEM retention. While many systems have become effective at introducing students to STEM activities, far fewer have successfully developed structures that sustain engagement over time.

The Importance of Identity, Belonging, and Purpose

Research and practice increasingly suggest that sustained STEM participation is shaped less by isolated activities and more by deeper human and social factors such as identity, belonging, mentorship, continuity, and purpose.

Students are more likely to remain engaged when STEM becomes connected to meaningful missions and societal contribution. Programs linked to environmental sustainability, healthcare innovation, artificial intelligence, accessibility technologies, lunar exploration, or community problem-solving tend to foster stronger long-term commitment because learners perceive themselves as contributing to something larger than the classroom.

Longitudinal engagement also plays a critical role. Sustained participation over months or years often produces greater impact than one-time high-intensity experiences. Students are more likely to persist when they can observe their own progression through leadership opportunities, advanced responsibilities, project ownership, peer mentoring, and public contribution.

Equally important is the concept of STEM identity. Many young people disengage not because they dislike science or technology, but because they do not perceive themselves as belonging within those spaces. Representation, mentorship, and visibility therefore become central to long-term ecosystem development. Students from regional communities, culturally diverse backgrounds, Indigenous communities, or underrepresented groups often remain engaged when they encounter relatable role models and inclusive learning environments that reinforce belonging.

Why Communication, Creativity, and Media Matter

Another important consideration is the integration of communication, creativity, and media within STEM ecosystems. Innovation increasingly depends not only on technical capability but also on storytelling, ethics, collaboration, and public engagement. Engineers must communicate ideas, scientists must engage communities, and innovators must navigate social impact.

Students who may initially feel disconnected from traditional STEM subjects often reconnect through digital storytelling, science journalism, animation, filmmaking, gaming, podcasts, design, or media-driven science communication. This reinforces the growing relevance of STEAM-oriented models.

The Role of Families, Communities, and Industry Exposure

Family and community ecosystems also significantly influence sustained participation. STEM engagement strengthens when scientific and technological aspirations become socially normalized within homes and communities. Public exhibitions, community showcases, local media visibility, council partnerships, and family participation all contribute to reinforcing the message that innovation is accessible and achievable.

Finally, authentic exposure to industry and research environments remains essential. Students are more likely to sustain interest when they can visualize future possibilities through interaction with engineers, researchers, startups, laboratories, universities, artificial intelligence systems, and real-world missions. Such experiences transform STEM from an abstract academic subject into a tangible pathway for contribution and leadership.

International Perspectives on Successful STEM Ecosystems

Internationally, some of the most effective STEM ecosystems demonstrate strong integration between education, research, entrepreneurship, public storytelling, national missions, and identity-building.

In South Korea, STEM has been linked closely to national technological identity. In Israel, innovation culture is deeply embedded within entrepreneurship ecosystems. In the United

States, space exploration and technological ambition continue to shape public imagination. In Finland, inquiry-driven education and student agency remain central to learning frameworks.

Reimagining the Future of STEM Ecosystems

For Australia and many other nations, the future challenge is therefore not simply increasing the number of STEM programs, but designing ecosystems that create continuity, belonging, leadership, and long-term participation.

Sustainable STEM ecosystems require movement away from isolated interventions toward connected developmental journeys that integrate education, mentorship, communication, public engagement, and societal purpose.

Ultimately, students remain in STEM not only because they learned science or technology, but because they began to see themselves as future contributors to innovation, research, and global problem-solving.

The importance of storytelling in scientific research

Pradeep Murthy
Tech and Partnerships Officer – AIMERS Foundation

At present, academia and research progress generally emphasises technical specialization, publication metrics, and interdisciplinary capability, all of which are useful and important. Across a myriad of research fields such as catalysis, materials science, artificial intelligence, and biotechnology, researchers are expected to pursue increasingly complex scientific and engineering challenges. Simultaneously, they must communicate their findings to diverse audiences including academics, industry stakeholders, policymakers, and the public domain. However, despite such technical information being conveyed, a truly important skill in doing so is often underestimated and misunderstood, namely storytelling.

This misunderstanding often arises from the incorrect perception that storytelling is incompatible with scientific rigour, objectivity, or analytical precision. However, the appeal in research communication is its dependence on developing a relatable narrative. Scientific papers, presentations, grant proposals, and technical reports are fundamental and coherent attempts in guiding readers through problems, evidence, reasoning, and conclusions.

This has been evident in my own research journey, which has combined process/chemical reaction engineering, material characterisation, techno-economic analysis and atomic-level simulations. This realisation of establishing a narrative emerged upon communicating through various forms, including journal articles, teaching, conference and poster presentations, industrial collaborations, and interdisciplinary projects including both technical and non-technical stakeholders. From my own perspective, research is a construction of understanding for wider audiences. The key information is clearly summarised and evidenced for others to read and utilise in some way.

Communicating research in a narrative style

It does seem that many early-career researchers approach scientific writing primarily as a form of information transfer, where, for example, their manuscripts treated as mere repositories of their findings and hoping that others can readily interpret the results. This could be due to students having studied sciences at secondary and tertiary-level and being more experienced with short-answer writing or being averse to public speaking or otherwise. In practice, scientific communication is naturally far more complex. The reader must acknowledge and appreciate an understanding of what the problem is and why it is worth solving in challenging or improving existing knowledge and approaches in this field, what was conducted in resolving it, what the findings were and how they are meaningful and relevant in a broader context.

Following this, research papers must rely on effective structure and progression alongside conceptual clarity. This is something that I have had to endure throughout my research journey, perhaps even more than merely obtaining (or not obtaining) results. In such fields as mine (catalysis and reaction engineering), research problems have often involved highly technical concepts spanning thermodynamics, kinetics, surface chemistry, materials science, and process optimisation, all of which require effective, yet simplified elaboration. Consequently, clarity of writing reflects clarity of understanding.

A narrative style within scientific communication can provide a cognitive structure instead of unnecessary or undesirable exaggeration and marketing. Strong scientific papers typically establish a key, motivating problem, limitations within existing knowledge, a proposed approach and hypothesis, supporting evidence, and arisen broader implications.

This mimics even a storybook style to ensure a smooth and seamless progression in which the reader is sufficiently guided through and understood of all technical concepts throughout the manuscript. Over time, I recognised that impactful scientific writing depends upon identifying the central idea(s) that readers should retain after reading the paper. This often requires prioritising conceptual clarity over excessive technical density.

Complexity and scientific understanding

One must innately balance scientific complexity and rigour with simple communication and perhaps even relatability. With increasing experience, researchers realise that simplifying their explanations can evoke easier comprehension for themselves and for the reader. For example, at first glance, explaining catalytic mechanisms, process interactions, or computational insights concisely appears more difficult than presenting large amounts of technical information.

Communicating complex ideas to wider audiences hence requires patience, structure, and conceptual clarity and organisation. Even a common profession as teaching can expose weaknesses in one's own understanding than the research itself. The same applies for industrial and interdisciplinary collaborations, where such projects as carbon capture feasibility and solar manufacturing analysis demonstrated the importance of translating complex analyses into understandable and actionable insights.

Finally, wider public audiences with varying technical backgrounds and understandings must also connect with the concepts, especially when the projects are related to policy, sustainability transitions, or other global societal challenges. Detailed, clear and even picturesque figures and tables could also tell "1000 words" as the saying goes in disseminating simplified perspectives and expressions. This broad range of environments reinforces the importance of storytelling techniques as a mechanism for connecting scientific ideas to human understanding.

Conclusions

Retrospectively, one valuable insight from my own research journey is that, as mentioned earlier, research is a construction of understanding, where such acquired knowledge is coherently structured and organised to ensure that others can interpret, critique, reproduce, and build upon it. This form of storytelling ensures that scientific rigour becomes accessible, meaningful, and ultimately impactful. As research fields continue to become technically advanced and interdisciplinary, communicating complex ideas clearly is expected to become increasingly important alongside technical expertise itself.

STEM *vs.* S.T.E.M.

Tibor G Molnar

Honorary Associate, Philosophy, University of Sydney

E-mail: Tibor.Molnar@sydney.edu.au

"[E]ducation is ... that which is left after all that has been learned has been forgotten." (Conant, 1943)

Part I

Abstract

In so-called 'STEM subjects', the academic achievement of Australian students appears to be in slow decline; and there seems to be little understanding of the underlying cause and what to do about it. This essay is an attempt at a solution: it develops a more nuanced definition of STEM, elaborates the questions of what STEM is *for*; why it matters; and how it might be better taught.

Keywords

STEM, STEAM, Scientific Literacy, Critical Thinking, Metaphysics, Analytic Philosophy, Science, Pure Science, Applied Science, Technology.

1. Introduction

"STEM" is a word on everyone's lips. Educators, academics, policymakers, and governments all sing its praises: as a source of jobs; as the answer to our economic woes; as "a pathway to a better Australia". (Office of the Chief Scientist, 2013) It is evident that STEM really matters! And we mustn't forget the Arts, of course, so the freshly-minted, all-inclusive, socially sensitive acronym is now "STEAM", or "STEaM".

Whichever is your favourite acronym, the common view is that there is a *crisis* in mathematics and science literacy; in Australia, (Harkin, 2023) in America, (Mullins, 1995) and perhaps elsewhere. While it's not exactly a "crisis", results from the OECD's Programme for International Student Assessment (PISA) do show that, among 15-year-old Australian students, there has been a 4-7% decline in mathematics and science literacy over the past 20 years.

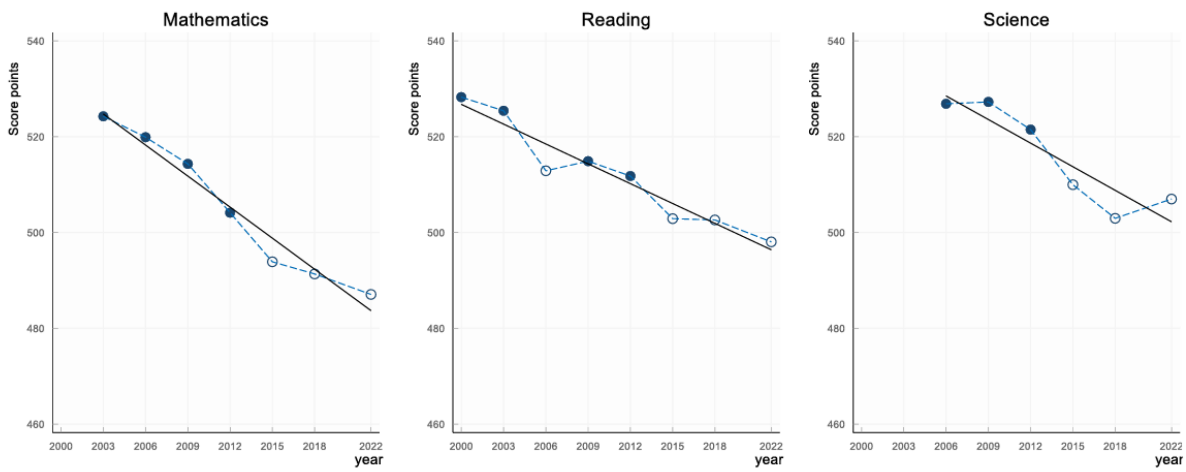


Figure 1: PISA 2022 results for Australia. (OECD, 2023)

This is hardly evidence of a "crisis", Australians perform well above the OECD average. Even its statistical significance is moot, [1] (Georgiou, 2025) but at a minimum the findings are not encouraging. (OECD, 2023)

We live in an age brimming with science and technology: an age powered by STEaM. But what exactly *are* "science" and "technology"; and how do they combine to become STEM, or STEaM? Is STEaM just a simple acronym – a collective term for five (or four) more-or-less closely related areas of human endeavour (**S**cience, **T**echnology, **E**ngineering, **A**rts, and **M**athematics); or is it, like LGBTQIA+, an acronym with a much deeper social, cultural, political and/or economic meaning?

According to Helen Georgiou there is no universally agreed definition of STEM; [2] [3] [4] so in this essay we derive our own. In so doing, we find that STEM is not – indeed cannot be – a simple combination of 'science', 'technology', etc., as is widely assumed. STEM turns out to be something else – something *more fundamental* [5] – and it plays a foundational role in our scientific understanding. In §3-§7 we elaborate this finding in some detail, and in §8 we conclude with a reassessment of STEM education and how it might be made more effective. After all, if STEM "really matters", it is important that it be taught well.

We start with some basic definitions.

1.1. Science

The word "science" derives from the Latin *scientia* (= knowledge), and in common usage it seems that anything we (can) *know* – anything that we can think about systematically and methodically ("scientifically", perhaps?) [6] – is called a 'science'. There are the *basic* sciences: chemistry, physics, biology, geology, astronomy; and the so-called '*special* ' sciences: e.g., biochemistry, geophysics, and medicine. And then there's social science; political science; domestic science; Christian Science; and others, whose status as a "science" may be open to question. In any case, Science is a very broad church!

"Science" has at least three different meanings: (1), collective human knowledge, as in "She knows her science!"; (2), the enterprise of systematic inquiry, as in "She's doing Science"; and (3), the methodology for validating knowledge, as in "A scientifically proven remedy". [7]

For our present purposes, we may simply accept anything that involves learning and/or knowing as 'science'; and divide it into two distinct, though closely related, programs:

---

[1] Helen Georgiou is Associate Professor of Science Education at the University of Wollongong, with particular expertise in conceptual learning, technology-enhanced teaching, and STEM engagement: < https://scholars.uow.edu.au/helen-georgiou >.
[2] The acronym was originally coined in 2014 as an aid for political lobbying (Fraser et al., 2019), but beyond this use, the term was not well defined.
[3] Helen Georgiou, in private conversation, March 28, 2025.
[4] See also: (Nielsen et al., 2019)
[5] Yes, I know… fundamentality does not come in degrees. That granted, I hope you get my meaning.
[6] More about systematic, methodical thinking in Section 3.3.
[7] This ambiguity is not entirely harmless and has given rise to what is known as the "Science Wars". See, for example, (Barnes & Bloor, 1982) and (Latour, 1999).

1.1.a. ***Pure Science***: the quest for *understanding* – figuring out what's going on and how things work – *without necessarily wishing to change anything*.

1.1.b. ***Applied Science***: the quest for *change* – working out what we can do to achieve particular outcomes – *without necessarily wishing to understand anything*.

'Pure' Science is the pursuit of discovery, explanation and understanding *for its own sake*: the quest to answer just one question: "What must the world be like, in order that it produce the phenomena we observe?". Astronomy, for example; or palaeontology – we study fossils to discover and understand the past, not to change it.

By contrast, 'Applied' Science is the application of our scientific understanding to the creation of tools and processes that enable us to manipulate and control our environment. An example is the development of the steam engine: we didn't build them just because we wanted to understand what happens when water boils. We had a purpose clearly in mind.

Of course, in practice, most 'scientific' activity has both 'pure' and 'applied' components, and in two ways: discovery and understanding often lead to new applications, and new applications often need new understanding. To understand the role of STEaM, however, it is helpful to identify/distinguish the two different motivations.

Applied Science is also known by another name: *Technology*. For simplicity, therefore, this essay will henceforth refer to Pure Science simply as 'Science', and Applied Science simply as 'Technology'.

1.2. Technology

We've already defined 'Technology' (at 1.1.b.), and there's not much left to say; except perhaps to highlight that Science and Technology are *complementary* processes: Science is the 'pursuit of causes' and Technology is the 'pursuit of effects'. The relation between Science and Technology is similar to the relation between cause and effect.

1.3. Engineering

Engineering may also be considered an Applied Science: it is putting Technology to work – applying our technological tools and processes to the manipulation and management of human affairs (and also to the development of new technologies).

1.4. Mathematics

Mathematics – more specifically *Applied* Mathematics [8] – is a tool that we have developed over the past 2,000+ years to help us plan, perform, and manage our daily affairs; including, but not limited to, our endeavours in science, technology and engineering.

Mathematics evolved out of the geometry and algebra of the Babylonians, [9] Greeks and Persians; the calculus of Newton and Leibniz; the symbolic logic of Boole and Russell; the set

[8] The other side of mathematics – Pure Mathematics – is the inquiry into the theory that underpins the structure and validity of mathematics. It includes, *inter alia*, the study of number theory, set theory, topology, formal logic, and the theory of countability and computability.

[9] See, for example, N. J. Wildberger & D. Mansfield: "Old Babylonian Mathematics and Plimpton 322: A new perspective": < https://www.youtube.com/watch?v=9o1FlKc_3aM >.

theory of Cantor and Zermelo; and the computational logic of Church and Turing. Its underlying logic defines what constitutes valid reasoning. [10]

1.5. Arts

Also, for simplicity, we may define the Arts as ‘everything that isn’t Science, Technology, Engineering, or Maths’ (though doubtless there is some overlap). Thus, the Arts includes sociology, economics, ethics, aesthetics, philosophy, music, poetry, literature, the fine arts, etc. – i.e., everything that we might gather under the rubric of the “humanities”.

Whereas Science tells us about the *physical* world – about how things work and what causes what – the Arts tells us about the *human* world: about how we think, feel, and respond to the goings-on in the world around us. It tells us what is important, how we should act, and why. It is through the Arts – i.e., through the humanities generally – that human existence acquires meaning and value; and it is the Arts that directs everything we do, including our scientific endeavours.

2. S.T.E.M.

Let us set the Arts aside for a moment (we’ll reintroduce it in the next section) and define S.T.E.M. as a straightforward shorthand expression for “Science, Technology, Engineering, and Mathematics” – the study and practice of the four disciplines that together enable humankind to understand and manipulate the “physical” world. We may depict our S.T.E.M. practices with this simple flowchart:

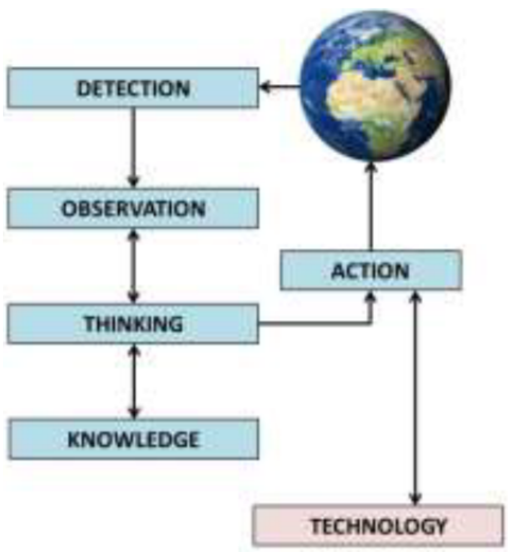


Figure 2. The S.T.E.M. process.

There is some ‘devil in the detail’, but the basic framework of S.T.E.M. is all there. ‘Science’ is the accumulation of ‘Knowledge’ about the world (*inter alia*); ‘Technology’ is the application of that ‘Knowledge’ to creating artefacts and tools; ‘Engineering’ is putting those tools to use to enable/enhance our ‘Actions’ in the world; and ‘Mathematics’ is a tool for measuring and predicting their effects. More specifically, we use our senses and instruments to

[10] But Logic does have its limits! See (Gödel, 1931) and (Turing, 1937).

detect and measure; we interpret what we find and record our observations; we think long and hard about how the world 'works'; and then figure out what actions to take to change what we don't like about it. Clever tool-using mammals that we are, along the way we invent various technological aids to help us bring about our desired outcomes. This is S.T.E.M. in a nutshell: the process whereby we construct and manage our complex technological world.

Accordingly, the most widely accepted definition of STEM is as a synonym for S.T.E.M.; i.e., as the aggregate of its four component disciplines. [11] (Spoiler alert: in §6, this essay will argue that STEM is *exactly not* synonymous with S.T.E.M.)

2.1. S.T.E.A.M.

Reintroducing the Arts, S.T.E.A.M. is simply the practice of S.T.E.M. with due regard/sensitivity for human/social concerns:

"Work in the social sciences and humanities is vital to our deep understanding of the societal context. And it is that context that will influence the extent to which STEM can be effective." (Office of the Chief Scientist, 2013)

(Another spoiler alert: in §7, this essay will argue that the acronym "S.T.E.A.M." is an incorrect characterisation of socially sensitive S.T.E.M. practice.)

2.2. The S.T.E.M. User's Manual

There is something missing, however. Figure 2 outlines the *practice* of S.T.E.M., but it tells us nothing about *how* we might go about practising it. Exactly how are we to distil the 'laws of nature' – the "rules" that seem to regulate worldly affairs – from simple observation? How might we establish/confirm that our understanding of worldly affairs is correct, or even coherent? And how might we determine the intended and unintended consequences arising from our various actions? Competence in S.T.E.M. (or S.T.E.A.M.) may suffice for a laboratory technician or construction site manager, but it's not enough for a research scientist or architect.

What is needed is a "User's Manual" – a detailed guide to *understanding* our S.T.E.M. practices, rather than just *doing* them – step-by-step instructions for *how* the practice of S.T.E.M. is to be conducted; for *why* it is best conducted in that way; and for *what* happens when we do (or don't). We also need precise guidelines for *making sense* of our findings, and for formulating an understanding of the physical world.

This User's Manual is not a simple document. [12] It has been in development for over 2,500 years, [13] and while it is now far advanced, [14] it is still not complete. Its ongoing elaboration and refinement is today an academic discipline of its own, commonly called the "Philosophy

---

[11] Jon D. Miller [1941-], research scientist emeritus at the University of Chicago, argued that Medicine should also be included, and introduced the term "STEMM". See: (Miller & Benbow, 2012), and (Miller & Solberg, 2012). Consistent with the definition at 1.1.b, this essay regards medicine as an applied science – as an application of biochemistry and biotechnology – and does not add the second "M".

[12] It is also not widely known or understood. See: Miller (2016).

[13] Thales of Miletus [*c*.626/3-*c*.548/5 BCE] was among the first to appeal to natural philosophy to explain the world. See Aristotle's *Organon* and *Metaphysics*; and also Bacon (1620a, 1620b), Herschel (1830), Whewell (1840), Peirce (1931-35), and Popper (2002).

[14] As testified by our many advanced technological successes.

of Science". A more correct characterisation might be "Philosophy *for* Science"; [15] for it is the deeper understanding and application of its principles that renders Science, erm..., "*scientific*". It is the apprehension and application of the User's Manual that distinguishes research scientists from laboratory technicians and turns machine operators into technological innovators.

However, people generally don't like reading manuals; [16] they are too impatient and prefer to fiddle around and work things out for themselves. This is as common among scientific researchers as it is among school students, and perhaps rightly so: spurred on by native curiosity and the thrill of discovery, "fiddling around" is how we learn *best*. [17]

S.T.E.M. education is *guided accelerated fiddling* – fuelling students' curiosity and provoking their learning. [18] There's a lot to learn, and the temptation is to rush: to focus on performance/results and neglect understanding; to concentrate on the practice and application of S.T.E.M. and forgo the study of the User's Manual. This is fine as far as it goes; [19] but we are now discovering that it doesn't go quite far enough. [20]

"Given the growing number of public policy issues that involve science or technology, the failure of the rate of civic scientific literacy to grow in the last decade is troubling." (Miller, 2016)

3. STEM

This essay argues that "STEM" refers not to S.T.E.M., but to the abovementioned User's Manual. STEM is an *adjunct to* S.T.E.M. – its theoretical underpinnings; its philosophical, logical, and scientific foundations. STEM is the glue that binds the disciplines of S.T.E.M. together and renders their practices meaningful. It is metaphysics; [21] formal logic; critical thinking; the scientific method; and the "Philosophy *for* Science" all rolled into one – the principles and rules on which all of our scientific knowledge and understanding are based. Strictly speaking, therefore, efficient practice in S.T.E.M. requires at least some understanding of STEM.

---

[15] For 14 years (2005-18), the author presented various 16- to 96-hour courses by this name at the Sydney University Centre for Continuing Education.

[16] Especially males.

[17] We've been 'fiddling around' for many thousands of years, and we've learnt a lot – both about the world, and about ourselves. Initially progress was slow (we were too busy struggling to feed ourselves); but in the last 200 years or so, our scientific knowledge and technological prowess has increased particularly rapidly; far beyond the point where it is possible for one person to know all that is known.

[18] For an example of how "guided accelerated fiddling" might be done, but mostly isn't, see (Whiteley, 2015).

[19] Recall that learning to drive a car does not require one to be a motor mechanic.

[20] Mightn't it be a good idea to learn what to do when the wheels fall off?

[21] The term "metaphysics" has an unusual history. In *c*.60 BCE, Andronicus of Rhodes, an editor of Aristotle's collected works, published "*Ta Meta Ta Physika*" (literally "that which comes after the Physics"), containing the 13 treatises of Aristotle that were traditionally arranged after those on the natural sciences. This has created much confusion ever since, for those 13 treatises cover material that is conceptually foundational to, and hence comes *before*, Physics. To make matters worse, "metaphysics" in contemporary parlance is also used to mean "that which is *beyond* the physical" – i.e., other-worldly, spiritual, and/or mystical. In this essay, the term is used in the Aristotelian sense of 'theoretical': beyond the reach of empirical science and foundational to scientific understanding.

STEM means different things to different people. For non-scientists, it is the metaphysics in terms of which to interpret the scientific (often mathematical) description of the physical world; for philosophers it is the bridge between the humanities and the sciences (the interface between the human world and the physical world); and for sociologists it is the human window onto worldly experience. For teachers, it's an educational challenge.

3.1. Metaphysics

Our scientific understanding is founded upon a number of conceptual, ontological, [22] and conceptual (epistemological [23]) assumptions (or axioms), in terms of which we make sense of the world, and of our place in it. We draw on our metaphysics to build a conceptual model of the world, and it is this model that we 'understand', and with which we interact. Broadly speaking, therefore, metaphysics defines the *language* and *semantics* of scientific understanding.

3.2. Logic

In the broadest sense, 'logic' is the computational machinery of *all* human thought. It includes systems of counting, geometry, and calculating; and of representing and manipulating mathematically the ordered patterns apparent in the world. It includes statistics (sorting like with like); deductive, inductive, abductive, (Peirce, 1931-35, 1958) and transcendental (Kant, 1787) reasoning; theories of validation and proof; and techniques for detecting and correcting fallacies. Broadly speaking, logic defines the *syntax* and *grammar* of scientific understanding.

3.3. 'Scientific Method'

The "scientific method" is a specification for optimal S.T.E.M. practice – a methodology for discovering, testing, and validating the 'knowledge' that we distil from our worldly experience. It is a guide to making our S.T.E.M. practices more reliable, and to detecting and correcting the errors that we make along the way. [24] [25]

The 'scientific method' does not apply to discovery and innovation; these are necessarily serendipitous rather than methodical. Rather, it describes the procedure for testing, validating, and proving new hypotheses/findings; and for checking their coherence and consistency against the existing canon of accepted theories.

---

[22] Ontology: the theory of 'existence' – of what there 'is', might be, or could be. [Gk: *on-* = being].
[23] Epistemology: the theory of 'knowledge' – of what we know or can know, and how we know it. [Gk: *epistemē* = knowledge].
[24] See for example, (Gauch, 2012), in particular pp. 267-270.
[25] Or maybe not! See: (Skinner, 1956), (Thurs, 2011), (Numbers & Kampourakis, 2015).

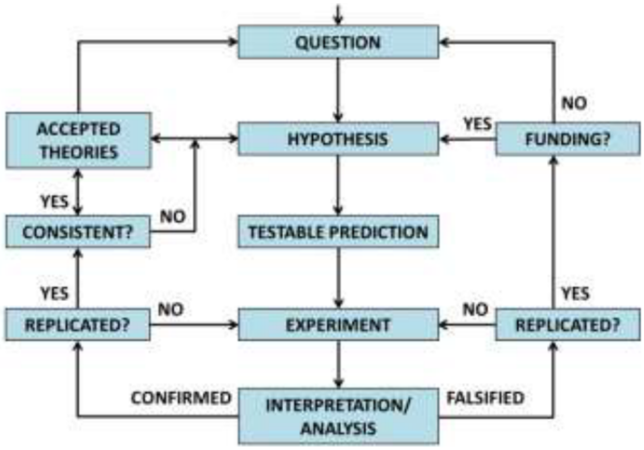


Figure 3 The 'Scientific Method'

This 'scientific method' has a complex history, spanning several centuries. (Bacon, 1620a; 1620b) Today there are several variants, and discussion among philosophers of science and further refinement is ongoing. [26]

3.4. S.T.E.M. + STEM

STEM is "all of the above": the compound of conceptual, abstract, and scientific thought – i.e., of metaphysics, logic, and the scientific method. Today, each of these is its own academic discipline. [27] In short, STEM is the difference between description and explanation; between understanding and simply knowing.

Adding STEM to the flowchart in Fig.1 yields something like this:

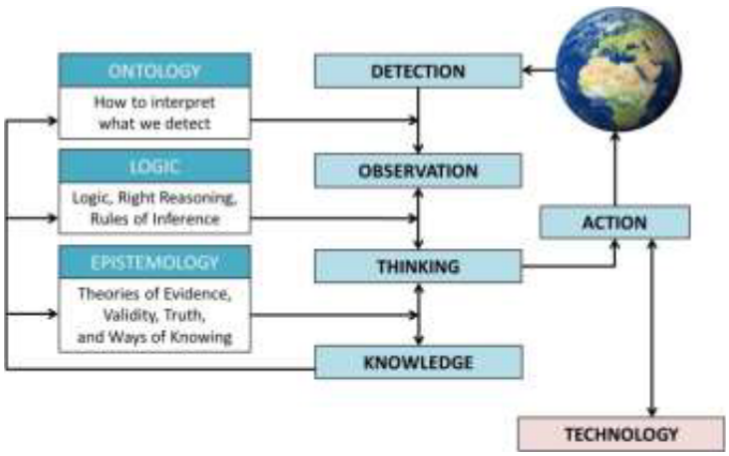


Figure 4. The STEM-enhanced S.T.E.M. process.

Figure 4 shows how closely STEM and S.T.E.M. are interconnected, and how there is constant feedback between them: [28] STEM informs the practice of S.T.E.M.; the knowledge so

[26] See, for example, < https://plato.stanford.edu/entries/scientific-method/ >.
[27] For more detail see, for example, (Quinton, 1973), (Simmons, 1961), (Popper, 2002).
[28] STEM is thus the thinking/understanding *behind* S.T.E.M., or '*beyond* ' S.T.E.M. Aristotle might have called it "meta-S.T.E.M.".

gained informs/updates the understanding encoded within STEM; this, in turn, better informs the future practice of S.T.E.M.; and so on, in an endless loop of innovation, discovery and learning. We may think of STEM and S.T.E.M. as, say, theory and practice, and their interplay is the mechanism whereby scientific knowledge and technology advances. [29]

3.5. Socially Responsible S.T.E.M. + STEM

Missing from Figure 4 is the provision of a mechanism for (*4c*) above – i.e., for deciding what constitutes "responsible decisions" and "good use". This is not an accidental omission however: judgements of human value are applicable to S.T.E.M., but *not* to STEM. STEM is the *theory of science* – the *description* of the *physical* world – independent of human/social values. [30]

Human interests/concerns may direct what science is/is not researched and what technology is/is not developed/deployed, and it may direct the order in which such research and development is conducted; but they have no influence over the scientific method or over what constitutes correct critical thinking. As defined in this essay, pure science and STEM are value neutral. [31]

"STEAM", therefore, is a misnomer: there's 'social value-sensitive S.T.E.M.', but not 'social value-sensitive STEM'. Only the enactment/deployment of science and technology (and its effects) are answerable to human/social concerns.

That said, we may add axiology [32] as a separate (i.e., external to STEM) contributor to the practice of S.T.E.M.:

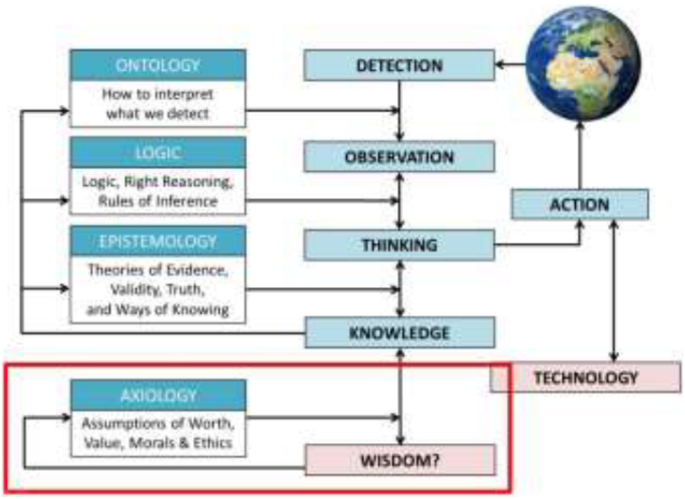


Figure 5. The 'social-value'-enhanced S.T.E.M. process.

[29] Accidental discoveries are an exception.

[30] For example: crop yields are crucially important to human flourishing; yet, regardless of its 'social value', the efficacy of C3 photosynthesis rapidly declines above 35°C. (Yamori, 2014).

[31] Indeed, it is 'human judgement', not STEM, that often *derails* S.T.E.M. – that leads to the misuse and abuse of science and technology. (It was human judgement, not STEM, that invoked the dropping of the bomb on Hiroshima.)

[32] Axiology: the theory and study of 'value' and 'worth', including of human values: good/bad, right/wrong, fairness/justice, and morals/ethics. [Gk: *axios* = worthy].

Centring S.T.E.A.M. around social values, however, is ultimately of questionable value: in the longer term (and often even in the short-term), a social-value-directed S.T.E.A.M. process is no better at promoting future human flourishing than a purely STEM-driven S.T.E.M. process. [33] The following case study illustrates the point:

The "greenhouse effect" has been known since 1856. (Foote, 1856; Arrhenius 1896). The 20th century has seen human flourishing beyond our wildest imaginings, mostly on the back of energy from fossil fuels. Even with the benefit of hindsight, what socially responsible "wisdom" could have been brought to bear in 1896 to decide whether or not to forgo a hundred years of technological advance and avert the attendant global warming? More particularly, what socially responsible "wisdom" could be brought to bear on this question *even today*? This is not a scientific question, and it is not a STEM question. It is a political question – with no possibility of a universally agreed political answer – arising from disagreement over the social and economic benefits/costs of the deployment of certain S.T.E.M. practices.

Demanding sensitivity to social values in S.T.E.M. matters clearly doesn't work. Accordingly, we show in §7 how S.T.E.A.M. is an incorrect characterisation of proper STEM practice.

…………………………………..To be continued in Part 2.

Acknowledgements

Thanks to Peter Baume, Helen Georgiou, Margret Schuller and Sam Sharp for their helpful comments.

[33] Somewhat cynically perhaps, we may also observe that moral/social values are more often employed in blaming other people's behaviour than in guiding one's own behaviour.

Paleoclimate Reconstruction Using Bivalve Proxies Linking Ocean pH and Growth Patterns at Lee Point, Gunn Point and Buffalo Creek

Jeswin Johnson, ASTA iCubed Finalist
E-mail: jeswin.johnson@outlook.com

Introduction

Earth's climatology has changed significantly over the past centuries due to the progressive increase in global temperatures (NASA Science, 2024). To adequately understand these fluctuations, paleoclimate reconstruction poses potential insights into historical environmental conditions. Paleoclimate reconstruction (PR) refers to the study of Earth's past climates using indirect evidence, or proxies such as sediments and fossilised organisms, to understand environmental conditions prior to the Anthropocene era (Bruckner, n.d.). Its importance lies in understanding both past and future climatic conditions that would otherwise remain unknown, allowing scientists to identify long-term climate trends.

One methodology used to determine such conditions is the analysis of proxies, which can record environmental changes over time. Among these proxies, bivalves are considered one of the most accessible and quantifiable means of determining past climates (Bieler & Mikkelsen, 2013). This article investigates the relationship between bivalve growth rings and ocean pH and evaluates their application in reconstructing past marine environments at Lee Point, Gunn Point and Buffalo Creek in the Darwin coastal region.

Background

Bivalves are aquatic molluscs that first appeared in the fossil record over 550 million years ago during the early Cambrian era and consist of over 10,000 species distributed globally (Bayne, 2017). Many species contain visible growth rings that can be used to estimate age, with each ring generally representing a year of growth caused by fluctuations in environmental factors such as temperature and nutrient availability (Watanabe et al., 2021).

The shells of bivalves contain large amounts of calcium carbonate ($CaCO_3$). Over time, calcium ions from the surrounding environment are incorporated into shell growth regions where calcium carbonate is deposited (Sillanpää et al., 2018). The pH of marine environments strongly influences this process. In alkaline conditions ($pH > 7$), calcium carbonate precipitates more easily, whereas acidic conditions ($pH < 7$) favour dissolution and reduce shell formation (NOAA, 2025). Consequently, well-preserved bivalves in sedimentary rocks suggest that historical marine environments were at least neutral to alkaline, as acidic conditions would have promoted shell dissolution.

Research suggests that during the Albian era, ocean pH was slightly lower than modern conditions due to elevated atmospheric carbon dioxide levels and disturbances to the global carbon cycle (Sun et al., 2016). Despite this, marine carbonate deposition still occurred extensively, allowing fossilised bivalves to remain preserved within sedimentary formations. These relationships form the basis for using bivalve growth patterns as proxies to estimate past ocean pH conditions (Patra & Punekar, 2025).

Main Focus of the Article

This investigation sampled dead bivalves from Lee Point, Gunn Point and Buffalo Creek within the Darwin coastal region. Surface seawater pH was measured at regular intervals using a calibrated pH probe, and growth rings were counted to estimate bivalve age. Fossilised bivalves collected from Gunn Point were also analysed and compared with modern specimens.

Statistical analysis was conducted using one-way ANOVA to determine whether significant differences in growth ring counts existed between sampling sites. Results demonstrated that Buffalo Creek, which exhibited the highest pH values, also showed the greatest average number of growth rings. Lee Point displayed lower pH values and correspondingly lower growth ring counts, while Gunn Point showed intermediate values.

A strong positive correlation ($R^2 = 0.8692$) was observed between ocean pH and growth ring count, suggesting that calcium carbonate deposition increases under more alkaline conditions. Fossilised bivalves collected from Gunn Point produced a mean growth ring value of approximately 21.8, corresponding to an estimated Albian-era pH of approximately 7.72, compared with a modern Gunn Point pH of 7.86. These findings suggest slightly more acidic ocean conditions during the Albian era, consistent with increased atmospheric CO_2 levels during this period (Sun et al., 2016).

The findings support the hypothesis that bivalve growth patterns may serve as a useful proxy for reconstructing past marine conditions. However, while strong correlations were observed, causation cannot be definitively established due to confounding environmental variables such as temperature, nutrient availability, shell erosion and biological variability between species. Furthermore, species identification could not be fully confirmed due to the absence of a taxonomist, which may have introduced additional variability into the investigation.

Despite these limitations, this investigation demonstrates that bivalve growth rings provide a relatively accessible and cost-effective approach for paleoclimate reconstruction when compared with more resource-intensive techniques such as isotopic analysis (Patra & Punekar, 2025).

Future Trends

As atmospheric carbon dioxide concentrations continue to rise, ocean acidification is expected to intensify and increasingly impact marine calcifying organisms (NOAA, 2025). Methods such as bivalve proxy analysis may provide a cost-effective alternative to traditional isotopic techniques for reconstructing historical marine conditions and understanding long-term environmental change.

Future studies could improve the reliability of this method by incorporating larger sample sizes, species-specific analysis, isotopic validation and broader geographic sampling locations. Additional environmental variables, including temperature and nutrient availability, could also be incorporated to improve the accuracy of paleoclimate reconstructions.

Conclusion

This investigation demonstrates that bivalve growth rings can serve as a useful proxy for reconstructing past ocean pH conditions. Statistical analysis identified a strong positive correlation between growth ring count and ocean pH, with fossilised bivalves suggesting slightly more acidic conditions during the Albian era compared with modern marine environments. Although limitations and confounding variables remain, this study supports the potential of bivalve proxies as an accessible approach for paleoclimate reconstruction and highlights opportunities for future research into historical marine environmental change.

References

Bayne, B. L. (2017). Evolution. In *Developments in aquaculture and fisheries science* (Vol. 41, pp. 47–87). Elsevier. https://doi.org/10.1016/B978-0-12-803472-9.00002-9

Bieler, R., & Mikkelsen, P. M. (2013). Bivalvia—A discussion of known unknowns. American Malacological Bulletin, 31(1), 123–133. https://doi.org/10.4003/006.031.0105

Bruckner, M. (n.d.). Paleoclimatology: How can we infer past climates? Science Education Resource Center, Carleton College. https://serc.carleton.edu/14930

NASA Science. (2024). Evidence. NASA. https://science.nasa.gov/climate-change/evidence/

National Oceanic and Atmospheric Administration. (2025). Ocean acidification. U.S. Department of Commerce. https://www.noaa.gov/education/resource-collections/ocean-coasts/ocean-acidification

Patra, S., & Punekar, J. (2025). Ocean acidification signals through deep time: A review of proxies. Evolving Earth, 3, 100056. https://doi.org/10.1016/j.eve.2024.100056

Sillanpää, J. K., Sundh, H., & Sundell, K. S. (2018). Calcium transfer across the outer mantle epithelium in the Pacific oyster, Crassostrea gigas. Proceedings of the Royal Society B, 285(1891), 20181676. https://doi.org/10.1098/rspb.2018.1676

Sun, Y., Li, X., Zhao, G., Liu, H., & Zhang, Y. (2016). Aptian and Albian atmospheric CO_2 changes during oceanic anoxic events: Evidence from fossil Ginkgo cuticles in Jilin Province, Northeast China. Cretaceous Research, 62, 130–141. https://doi.org/10.1016/j.cretres.2015.12.007

Watanabe, T., Suzuki, M., Komoto, Y., Shirai, K., & Yamazaki, A. (2021). Daily and annual shell growth in a long-lived freshwater bivalve as a proxy for winter snowpack. Palaeogeography, Palaeoclimatology, Palaeoecology, 569, 110346. https://doi.org/10.1016/j.palaeo.2021.11034

The ASTA iCubed Awards program is a collaboration between all members of the ASTA Federation, comprising each state and territory's Science Teachers Association and the ASTA Secretariat. The program celebrates inquiry, innovation and ingenuity across Australian school students of STEM to provide a truly national reach. The ASTA iCubed Awards targets primary and secondary school students across Australia, with a special emphasis on engaging all students from our diverse cultural, socioeconomic and geographical populations.

Maximising the Adsorption Capacity of Chitosan Beads using Marble Powder for Tartrazine Dye Removal

Harima Ali
Queensland Academy for Health Sciences, ASTA iCubed Finalist
E-mail: harima.wahvillage@gmail.com

Introduction

The decline in water quality caused by industrial pollutants has become an increasingly significant environmental issue worldwide. Azo dyes are widely used in industrial processes and frequently enter waterways through textile and manufacturing wastewater. Due to their chemical stability, these dyes are difficult to remove using conventional wastewater treatment methods. Exposure to azo dyes has been associated with environmental toxicity and harmful effects on human health. (Nguyen & Saleh, 2020).

Adsorption is recognised as an effective wastewater treatment method due to its low cost and efficiency (Aksu, 2004). Chitosan has been widely investigated because of the abundance of hydroxyl (-OH) and cationic primary amine ($-NH_3^+$) groups that contribute to adsorption (Aranaz et al., 2021). Marble powder has also recently been recognised for its adsorptive abilities and high specific surface area (Chen et al., 2024).

This article investigates whether the addition of marble powder can improve the adsorption capacity of gelatinised chitosan beads for tartrazine dye removal.

Background

Azo dyes are synthetic dyes characterised by azo bonds and are commonly used in textiles. Their chemical stability makes them resistant to degradation, allowing them to persist in aquatic environments (Nguyen & Saleh, 2020). Current wastewater treatment methods can often be expensive or inefficient, particularly in developing countries where financial resources may be limited (Martínez-Huitle, 2014).

Chitosan has been extensively investigated as an adsorbent because of its positively charged amine groups, which can attract negatively charged dye molecules through electrostatic attraction (Sarıkaya et al., 2012; Oancea & Meltzer, 2013). Previous research has also shown that adsorption is an effective and low-cost treatment method for dye-contaminated wastewater (Aksu, 2004).

Marble powder has recently been investigated for its adsorptive abilities due to its large surface area and low cost (Chen et al., 2024). Therefore, combining chitosan with marble powder may improve adsorption capacity whilst also reutilising waste materials that are simultaneously biodegradable.

To synthesise beads, ionic crosslinking is typically utilised, which is costly. However, an unpublished method was found that can be used to synthesise beads from chitosan is gelation. This method for bead formation was encountered in a publicly available video (Renaye Zdunich, 2017). In this process, a solution of chitosan dissolved in acetic acid is dropped into a sodium hydroxide (NaOH) solution. The NaOH neutralises the acetic acid, and as the pH increases, chitosan, which is only soluble in acidic conditions, precipitates out of solution, forming gel-like beads (Maiz-Fernández et al., 2022). This approach does not involve chemical crosslinkers, and while it may result in beads with lower structural stability, it has potential advantages in contexts where affordability and simplicity outweigh durability. This method is being explored here as a possible novel and low-cost alternative to crosslinking, particularly for developing countries.

Main Focus of the Article

Preliminary experiments demonstrated that gelatinised beads outperformed crosslinked beads in dye adsorption. The addition of marble powder increased adsorption capacity, particularly in basic conditions. Therefore, gelatinised chitosan beads and chitosan-marble powder beads were selected for further investigation at pH 0 and pH 14 respectively.

Chitosan powder was magnetically stirred with 2% acetic acid until fully dissolved. Half of the solution was dropped into 0.25M NaOH solution allowing for the formation of chitosan beads. To the remaining dissolved chitosan, marble powder was added before being dropped into NaOH solution, allowing for the formation of chitosan-marble powder beads. The beads were dried at 40°C and stored for experimentation.

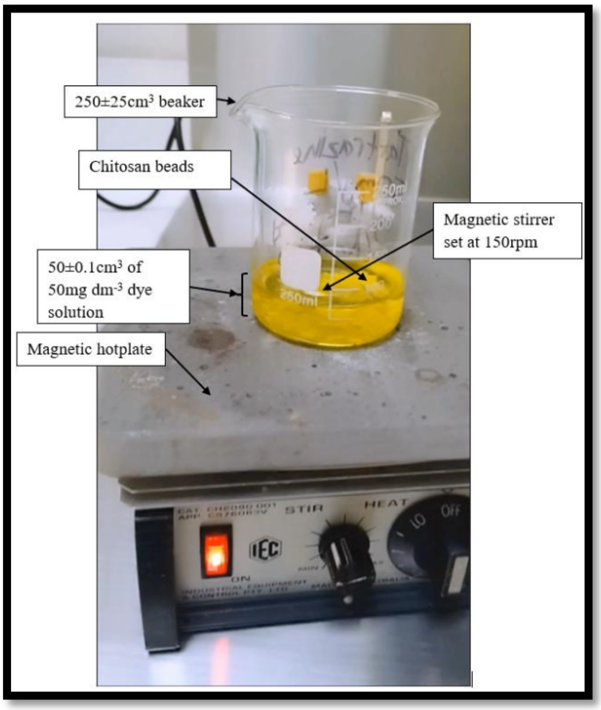


Figure 1: Real Example of a Static Adsorption Trial, with Beakers filled with pH 0 solution and Chitosan Beads at 150rpm Magnetic Stirring at

Static adsorption experiments were conducted using 1.500±0.001g of beads in 50cm^3 of 50mg dm^{-3} tartrazine solution for 95 minutes. Chitosan beads were tested in pH 0 solution while chitosan-marble powder beads were tested in pH 14 solution. Absorbance measurements were collected every 5 minutes using UV-visible spectrophotometry. A demonstration of this can be seen above in Figure 1.

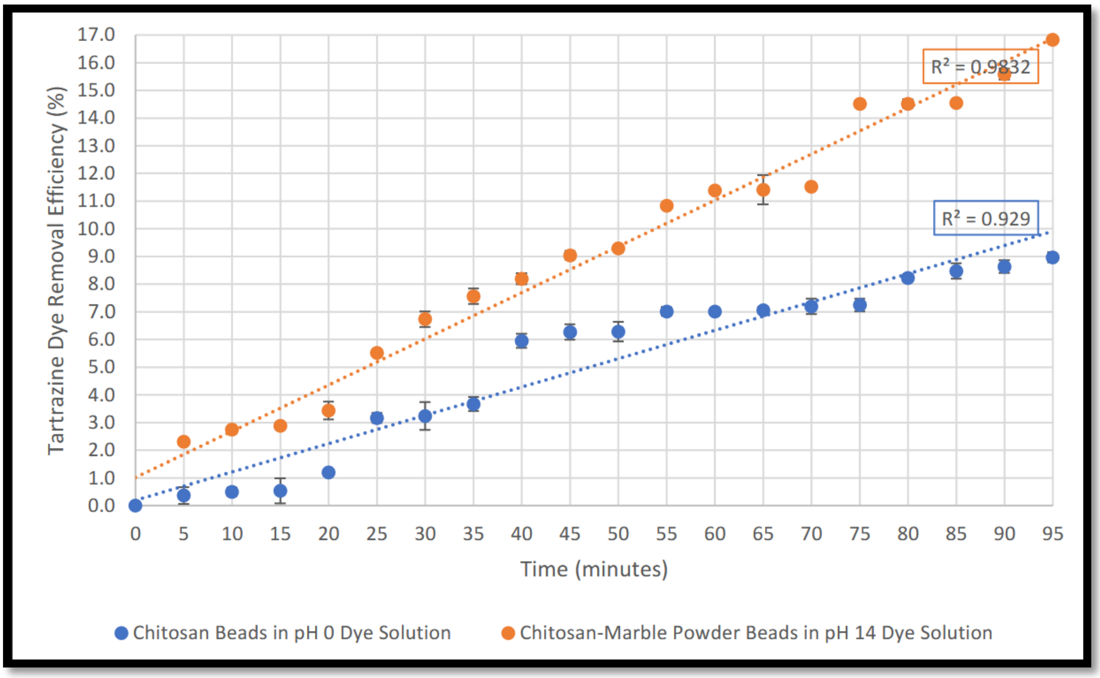


Figure 2: Graphical Representation of the Average Percent Dye Removal Efficiency

Graph 1 compares the average percent dye removal efficiency of chitosan beads and chitosan-marble powder beads over 95 minutes.

The results demonstrated that dye removal increased with contact time for both bead types. The chitosan-marble powder beads demonstrated a noticeably greater adsorption capacity than the chitosan beads alone, achieving 16.8% dye removal compared to 9.0%. The increased adsorption is likely due to the increased surface area introduced by marble powder ("Effects of Cement-marble Waste Powder Paste Volume on the Rehology of Self-compacting Concrete," 2018).

Although no major colour changes were observed in the tartrazine solution throughout the 95-minute period, degradation of the chitosan-marble powder beads was observed during the adsorption experiment.

Kinetic modelling showed that the pseudo-first-order (PFO) model produced a higher R^2 value than the pseudo-second-order (PSO) model (0.9047 vs 0.487), suggesting that physisorption dominated the adsorption process through weak van-der-Waals interactions (Ho & McKay, 1999). This suggests that the beads may be reusable, further supporting their environmental sustainability and cost-effectiveness.

The investigation was limited by bead degradation and the absence of equilibrium data. Dye degradation over time may also have affected absorbance values and calibration accuracy.

Overall, the chitosan-marble powder composite demonstrates strong potential as an alternative to traditional wastewater treatment methods due to its enhanced adsorption capacity, potential reusability, and utilisation of biodegradable waste materials.

Future Trends

Future investigations could test the reusability of the beads within more realistic wastewater pH ranges (6–8) and investigate lower dye concentrations and a wider variety of dyes. Further research into scalability and long-term adsorption performance may also improve understanding of the practical applications of chitosan-marble powder composites in wastewater treatment.

Conclusion

The addition of marble powder successfully increased the adsorption capacity of gelatinised chitosan beads for tartrazine dye removal. Chitosan-marble powder beads achieved a higher dye removal efficiency than chitosan beads alone, demonstrating the potential of marble powder to enhance adsorption performance.

Further data analysis suggested that physisorption governed the adsorption process, indicating the possibility of reusing the beads. Overall, this composite demonstrates strong potential as a low-cost and environmentally sustainable alternative for wastewater treatment whilst also reutilising biodegradable waste materials.

Acknowledgements

I wish to acknowledge my parents, Dr Mohsin Ali and Mrs Humaira Mohsin, my supervisor, Mrs Kahlia Baker, and the Head of Science at my school, Mr Anir Lal, for their guidance and support throughout this investigation.

References

Aksu, Z. (2004). Application of biosorption for the removal of organic pollutants: a review. Process Biochemistry, 40(3–4), 997–1026. https://doi.org/10.1016/j.procbio.2004.04.008

Al-Tohamy, R., Ali, S. S., Li, F., Okasha, K. M., Mahmoud, Y. A., Elsamahy, T., Jiao, H., Fu, Y., & Sun, J. (2022). A critical review on the treatment of dye-containing wastewater: Ecotoxicological and health concerns of textile dyes and possible remediation approaches for environmental safety. Ecotoxicology and Environmental Safety, 231, 113160. https://doi.org/10.1016/j.ecoenv.2021.113160

Aranaz, I., Alcántara, A. R., Civera, M. C., Arias, C., Elorza, B., Caballero, A. H., & Acosta, N. (2021). Chitosan: An overview of its properties and applications. Polymers, 13(19), 3256. https://doi.org/10.3390/polym13193256

Chen, Q., Liao, J., Zeng, S., & Zhou, L. (2024). Facile Fabrication of Porous Adsorbent with Multiple Amine Groups for Efficient and Selective Removal of Amaranth and Tartrazine Dyes from Water. Materials, 17(10), 2391. https://doi.org/10.3390/ma17102391

Effects of cement-marble waste powder paste volume on the rehology of self-compacting concrete. (2018). In Conference Paper.

Ho, Y., & McKay, G. (1999). Pseudo-second order model for sorption processes. Process Biochemistry, 34(5), 451–465. https://doi.org/10.1016/s0032-9592(98)00112-5

Maiz-Fernández, S., Pérez-Álvarez, L., Silván, U., Vilas-Vilela, J. L., & Lanceros-Méndez, S. (2022). PH- Induced 3D printable Chitosan hydrogels for soft actuation. Polymers, 14(3), 650. https://doi.org/10.3390/polym14030650

Martinez-Huitle, C.A. (2014). Organic Pollutants in Water Using BDD, Direct and Indirect Electrochemical Oxidation. In: Kreysa, G., Ota, Ki., Savinell, R.F. (eds) Encyclopedia of Applied Electrochemistry. Springer, New York, NY. https://doi.org/10.1007/978-1-4419-6996-5_92

Nguyen, T. L., & Saleh, M. A. (2020). Thermal degradation of azobenzene dyes. Results in Chemistry, 2, 100085. https://doi.org/10.1016/j.rechem.2020.100085

Oancea, P., & Meltzer, V. (2013). Kinetics of tartrazine photodegradation by UV/H2O2 in aqueous solution. Chemical Papers, 68(1). https://doi.org/10.2478/s11696-013-0426-5

Sarıkaya, R., Selvi, M., & Erkoç, F. (2012). Evaluation of potential genotoxicity of five food dyes using the somatic mutation and recombination test. Chemosphere, 88(8), 974–979. https://doi.org/10.1016/j.chemosphere.2012.03.032

Yogeshwaran, V., & Priya, A. (2020). Adsorption of lead ion concentration from the aqueous solution using tobacco leaves. Materials Today Proceedings, 37, 489–496. https://doi.org/10.1016/j.matpr.2020.05.467

Promoting our Profession,
Enriching Science Teaching
for 75 Years

The ASTA iCubed Awards program is a collaboration between all members of the ASTA Federation, comprising each state and territory's Science Teachers Association and the ASTA Secretariat. The program celebrates inquiry, innovation and ingenuity across Australian school students of STEM to provide a truly national reach. The ASTA iCubed Awards targets primary and secondary school students across Australia, with a special emphasis on engaging all students from our diverse cultural, socioeconomic and geographical populations.

Thorium Liquid-Fuel Machines: A New Hope for Cancer Patients Through Reliable Isotope Production

Dusya Lyubovskaya, Thorium Network

Introduction

Cancer remains one of the leading causes of death worldwide, and many patients face limited treatment options when their disease reaches advanced or terminal stages (World Health Organization [WHO], 2023). Modern therapies such as chemotherapy, immunotherapy, and radiation have improved outcomes, but some treatments depend on special medicines called radioisotopes, which are unstable or hard to produce reliably (Sung et al., 2021; Parker et al., 2018).

This article explores thorium liquid-fuel machines—advanced nuclear systems that could produce these life-saving isotopes continuously. The goal is to explain how these systems work, compare them with current production methods, and show how they could help cancer patients receive more timely and effective treatments.

Background

Medical Isotopes and Cancer Therapy

Radioisotopes are radioactive substances used in medicine for diagnosis (imaging tumors) and therapy (killing cancer cells). Common isotopes include technetium-99m (Tc-99m) for scans, and lutetium-177 (Lu-177) or actinium-225 (Ac-225) for targeted radiation therapy (Dash & Chakravarty, 2019).

These isotopes are typically produced in aging nuclear reactors or cyclotrons, which can be slow, expensive, and prone to interruptions (IAEA, 2021). Even brief outages can delay treatments, sometimes putting patients at serious risk.

Thorium Liquid-Fuel Machines

Thorium liquid-fuel machines, also known as liquid-fission systems, dissolve nuclear fuel in molten salt, allowing it to flow continuously through the reactor (LeBlanc, 2010). Unlike traditional solid-fuel reactors, these machines can:

- Produce isotopes without shutting down the reactor
- Operate safely with passive safety features
- Generate energy while producing medicine
- Potentially create a wider variety of isotopes for therapy

When thorium (^{232}Th) absorbs neutrons, it turns into uranium-233 (^{233}U), which sustains the nuclear reaction needed to make isotopes (IAEA, 2005).

Evidence from Preclinical Research

Preclinical studies using thorium-227 conjugates—radioactive molecules linked to cancer-targeting antibodies—show that alpha radiation can selectively destroy cancer cells while sparing healthy tissue (Juzeniene et al., 2018; Kratochwil et al., 2016).

These results suggest that reliable thorium-based isotope production could help extend survival for terminal cancer patients, offering treatments that were previously limited by supply constraints.

Main Focus of the Article

Why Current Systems Are Limited

Today, most isotopes come from a few reactors worldwide. For example:

- Molybdenum-99 decays to Tc-99m, crucial for imaging, but its production is concentrated in just a few countries.
- Therapeutic isotopes like Lu-177 and Ac-225 are even rarer, slowing adoption of promising therapies (Sartor et al., 2021).

Interruptions in supply can delay patient treatments by weeks, reducing effectiveness and increasing anxiety for terminal patients.

How Liquid-Fuel Systems Could Help

Thorium liquid-fuel machines offer several advantages:

1. Continuous Isotope Production: The circulating fuel allows isotopes to be extracted without stopping the reactor.
2. Flexibility: Can produce multiple isotopes, including advanced alpha emitters for targeted cancer therapy.
3. Safety: Passive safety reduces risk compared to solid-fuel reactors.
4. Patient Benefit: Reliable production means patients can receive treatments on schedule, potentially improving survival and quality of life.

Future Trends

Thorium liquid-fuel machines are still largely in the research and development stage, but several emerging trends suggest their potential impact on cancer care:

1. Clinical Translation of Thorium-227 Therapies: Early-phase trials are exploring targeted alpha therapy in humans, potentially expanding treatment options for metastatic cancers (Juzeniene et al., 2018; Kratochwil et al., 2016).
2. Modular Deployment Near Hospitals: Smaller reactors could reduce delivery times for isotopes, supporting rapid clinical responses.
3. Integration with Energy Production: Simultaneous electricity generation and isotope production may improve cost-efficiency.

4. Optimization of Isotope Extraction: Advanced chemical separation will maximize isotope yield and minimize decay loss.
5. Regulatory Framework Development: New safety and quality standards will ensure safe clinical implementation.
6. Global Access: Decentralized isotope production could improve equitable access to advanced therapies worldwide.

Table 1: Comparing Current Isotope Infrastructure and Thorium Liquid-Fuel Machines

Feature	Current Reactors / Cyclotrons	Thorium Liquid-Fuel Machines
Production Type	Solid fuel targets, accelerator	Molten salt liquid fuel, continuous circulation
Supply Reliability	Vulnerable to outages and maintenance	Continuous extraction possible, less disruption
Isotope Variety	Limited (Tc-99m, Lu-177)	Tc-99m, Lu-177, Ac-225, and more
Operational Safety	Standard nuclear protocols	Passive safety features, reduced long-lived waste
Patient Benefit	Treatment delays common	Timely access to therapy, potentially improved outcomes
Visual Icon	🏭	

Conclusion

Cancer patients at advanced or terminal stages often face limited options, and timely access to therapeutic isotopes can directly influence outcomes. Current isotope production is concentrated in a few aging facilities, creating vulnerabilities in global supply chains.

Thorium liquid-fuel machines—advanced reactors where nuclear fuel flows in molten salt—offer a promising alternative. They allow continuous, flexible, and safe isotope production while generating energy. Preclinical evidence using thorium-227 conjugates demonstrates that alpha-emitting therapies can selectively destroy cancer cells, supporting the concept that reliable thorium-based isotope supply could extend survival and improve quality of life.

While full clinical deployment will require engineering optimization, regulatory adaptation, and further research, these systems represent a new hope for terminal cancer patients, bridging gaps in medical isotope access and potentially saving lives.

Acknowledgements

The author wishes to acknowledge colleagues in nuclear medicine, preclinical research teams, and thorium reactor specialists for their guidance and insights, which informed the development of this article.

References

Dash, A., & Chakravarty, R. (2019). Production of therapeutic radionuclides for cancer therapy. Journal of Nuclear Medicine, 60(4), 500–508. https://doi.org/10.2967/jnumed.118.220317

Juzeniene, A., Bruland, Ø. S., & Dahle, J. (2018). Preclinical evaluation of thorium-227 conjugates for targeted alpha therapy. Frontiers in Oncology, 8, 400. https://doi.org/10.3389/fonc.2018.00400

Kratochwil, C., Bruchertseifer, F., Giesel, F. L., Weis, M., Verburg, F., Mottaghy, F., & Haberkorn, U. (2016). Targeted alpha therapy of metastatic castration-resistant prostate cancer with 225Ac-PSMA-617: Dosimetry estimate and clinical outcome. Journal of Nuclear Medicine, 57(12), 1941–1947. https://doi.org/10.2967/jnumed.116.176303

LeBlanc, D. (2010). Molten salt reactor: A safer and more efficient nuclear power option. Progress in Nuclear Energy, 52(2), 105–116. https://doi.org/10.1016/j.pnucene.2009.11.005

Parker, C., Nilsson, S., Heinrich, D., Helle, S., O'Sullivan, J. M., Fosså, S. D., … & Sartor, O. (2013). Alpha emitter radium-223 and survival in metastatic prostate cancer. New England Journal of Medicine, 369, 213–223. https://doi.org/10.1056/NEJMoa1213755

Sartor, O., de Bono, J., Chi, K. N., Fizazi, K., Herrmann, K., Rahbar, K., … & Kratochwil, C. (2021). Lutetium-177–PSMA-617 for metastatic castration-resistant prostate cancer. New England Journal of Medicine, 385, 1091–1103. https://doi.org/10.1056/NEJMoa2107322

Sung, H., Ferlay, J., Siegel, R. L., Laversanne, M., Soerjomataram, I., Jemal, A., & Bray, F. (2021). Global cancer statistics 2020: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA: A Cancer Journal for Clinicians, 71(3), 209–249. https://doi.org/10.3322/caac.21660

World Health Organization. (2023). Cancer. https://www.who.int/news-room/fact-sheets/detail/cancer

IAEA. (2021). Nuclear medicine resources: Current challenges in isotope supply. International Atomic Energy Agency. https://www.iaea.org/resources

Quantum Chemistry

Kshitij Srivastava, Phd Chemical Engineering

Quantum chemistry serves as the essential bridge between the abstract laws of quantum mechanics and the observable behaviour of chemical systems. At its core, the field seeks to solve the Schrödinger equation for molecular systems to predict properties that are otherwise difficult or impossible to measure experimentally.

Fundamental Framework

The central challenge in quantum chemistry is the many-body problem. While the Schrödinger equation can be solved exactly for one hydrogen atom, adding even a single electron introduces complex inter-electronic repulsions. To manage this, the field relies on the Born-Oppenheimer approximation, which assumes that, because atomic nuclei are much heavier and slower than electrons, we treat nuclei as fixed points while calculating the electronic motion.

Computational Approaches

To approximate the behaviour of electrons in a molecule, two primary frameworks dominate the literature of computational chemistry:

1. Wavefunction Theory (WFT): Methods like Hartree-Fock (HF) and Coupled Cluster (CC) attempt to find a many-electron wavefunction. While CC is often called the "gold standard" for accuracy, its computational cost scales steeply with electrons, limiting it to smaller systems.

2. Density Functional Theory (DFT): Rather than focusing on a complex wavefunction, DFT uses electron density as the fundamental variable. Based on the Hohenberg-Kohn Theorems, DFT provides a much more computationally efficient way to study large molecules and solid-state materials, though it relies on the approximations of the "exchange-correlation" functional to account for electron interactions.

Applications of Quantum Chemistry in Modern Research

Quantum chemistry with such frameworks is no longer just a theoretical exercise; it is a predictive tool used across various domains:

- Thermodynamics and Kinetics: Researchers use quantum calculations to determine the transition states of reactions, allowing them to predict the reaction rates and identify the most stable molecular configurations.
- Spectroscopy: By calculating the energy difference between quantum states, Infrared (IR), X-Ray Diffraction (XRD), Nuclear Magnetic Resonance (NMR), and UV-Vis spectra can be simulated to verify experimental results.
- Materials Discovery: Quantum chemistry is pivotal in designing new catalysts, battery electrolytes, and semiconductors. By simulating how molecules interact at an interface, researchers can "screen" materials in a virtual lab before ever stepping into a physical one.

The Frontier: Quantum Computing

The next evolution of the field lies in Quantum Information Science. Traditional "classical" computers struggle to simulate large quantum systems because the memory required grows exponentially with the size of the molecule. Quantum computers, which use qubits that can exist in multiple states simultaneously, are naturally suited to simulate molecular orbitals. This shift promises to unlock the ability to model complex biological enzymes and high-temperature superconductors with unprecedented precision.

------------------------ xxxxxxxxx------------------------

AutoBerryPicker: Engineering a Solution for Ethical Agriculture

Xavier Phillips, Viewbank College, Melbourne

When I started planning my VCE Systems Engineering project, I knew I didn't just want to build a machine that moved things from point A to point B. I wanted to tackle a genuine, real-world problem. After researching global issues, I decided to focus on the United Nations' Sustainable Development Goal (SDG) #8: *Decent Work and Economic Growth*. Specifically, I wanted to target SDG 8.7, which aims to eradicate forced labour, modern slavery, and child labour.

The statistics are confronting. Recent estimates suggest that 160 million children are involved in child labour worldwide. That is roughly 1 in 10 children. A huge amount of this exploitation happens in the agriculture industry, where vulnerable people are forced to manually harvest small crops like cotton and berries.

This is where the concept for the "AutoBerryPicker" came from. My goal was to design an affordable, automated robotic arm that could use a camera to find crops and carefully pick them. If we can build low-cost robots to do this work, we can provide a viable alternative to using child labour, while also potentially reducing food waste and improving efficiency.

For this project, I chose to focus on picking strawberries. They are soft, easily bruised, and require a delicate touch, making them the perfect "worst-case" test for a robotic gripper. If my robot could pick a strawberry without smashing it, the design could easily be adapted for tougher crops later.

Designing the Robot

Building a robot from scratch as a solo student developer means dealing with strict constraints. I had a budget of just $150, the robot had to weigh less than 5 kilograms, and it needed to run off a standard 12V power supply or battery so it could be portable.

These limits meant I had to be very careful about what kind of robot arm I built. I looked at Cartesian robots (like 3D printers), but they need too much frame material to get a good reach. I also looked at articulated arms (like the ones in car factories). They are precise, but they require expensive motors and very complex math to control.

In the end, I chose a polar, or spherical, robot design. This setup uses a rotating base to turn left and right, a second motor to lift the arm up and down, and a linear actuator that extends and retracts to reach the fruit.

This design gave me a great range of motion without blowing the budget or making the code impossibly hard to write. I modelled the parts in Onshape and 3D printed them using PLA plastic to keep it light. For the extension, I used a cheap 12V DC linear actuator with a 150mm stroke. For the rotation and lifting, I used MG996R servo motors.

I ran into a major physics problem early in the design phase. When I modelled the arm as a lever, I realised that when the arm was fully extended, the weight of the gripper and the actuator would put a massive strain on the lifting motor. The torque required was way higher than what my cheap servo motor could handle. To fix this, I redesigned the mount to include an aluminium counterweight on the back. This balanced the arm like a seesaw, taking the load off the motor and stopping it from burning out.

Giving the Device Sight

For the AutoBerryPicker to actually work, it needs to see the strawberries and find them in 3D space. Industrial robots often use expensive stereoscopic 3D cameras, but I had to stick to my budget, so I used a standard 1080p webcam.

I wrote the vision software in Python using a library called OpenCV. To find the fruit, the program looks for colour. I built a tool that let me tune "Hue, Saturation, and Value" (HSV) sliders to filter the image. By tweaking these values, I could get the camera to ignore green leaves and unripe fruit and only see the specific red colour of a ripe strawberry.

It worked surprisingly well. In my diagnostic tests, I put the robot in front of a mix of strawberries, blueberries, blackberries, and grapes. The vision system had a 0% false-positive rate. It ignored everything except the strawberries.

Controlling the Movement

Once the camera sees a red blob, the software draws a box around it and finds the centre point. The hard part is getting the motors to move the arm so that the centre of the camera frame lines up with the centre of the strawberry.

To do this smoothly, I implemented a Proportional-Integral-Derivative (PID) controller. This is a control loop mechanism used in industrial systems. It calculates the "error" (how far away the arm is from the target) and adjusts the motors to fix it.

Proportional (P): This looks at where the arm is right now. If the error is big, it moves the arm fast. If the error is small, it moves slowly.

Integral (I): This looks at the past. If the arm gets stuck close to the target but won't quite reach it (maybe due to friction), the "I" term builds up power over time to give it that final push.

Derivative (D): This predicts the future. It looks at how fast the error is changing and applies a "brake" to stop the arm from shooting past the target and wobbling back and forth.

I had to write a separate program just to tune these values. I graphed the error over time and adjusted the numbers until the arm stopped oscillating and started locking onto the target quickly and smoothly.

Once the strawberry is centred, the robot triggers the picking sequence: it extends the arm, closes the 3D-printed gripper using a small micro-servo, and then retracts to pull the berry off the plant.

The Reality of Prototyping

Moving from a computer model to a real machine teaches you lessons you can't learn in a classroom. The development process was extremely iterative. I relied heavily on my 3D printer. Every time something broke or didn't fit, I would redesign the part and print a new one.

For example, early in testing, the rotation axis wasn't moving correctly. The gears were slipping because the 3D-printed shaft connecting the motor to the arm was too thin and relied on friction to hold it in place. It actually snapped in half while I was handling it. I went back to Onshape, redesigned the shaft to be much thicker, and added a hole so I could bolt it directly to the motor horn. This completely solved the problem.

I also put the finished device through a series of diagnostic tests to see if it actually met the criteria I set at the start of the year. The accuracy was great. The PID system consistently got the arm within 10% of the target position. I also tested the power consumption. I ran the robot off a wall adapter and then off a 12V battery. I timed the movements and did a statistical analysis on the results. The p-value was 0.7583, which means there was no significant difference in performance. This proved that the robot is genuinely portable and could run on a battery in a field.

However, the testing also revealed some serious limitations. I did a stress test to see how much weight the gripper could hold. I loaded it up with 500g, which turned out to be too much. The gears inside the lifting motor sheared off completely, and the arm collapsed. It was a catastrophic failure, but it was a valuable lesson about the physical limits of hobby-grade parts. I replaced the motor, but I learned that for a commercial version, I would need much stronger metal-gear servos.

The biggest issue was the speed. My original goal was to pick 6 strawberries per minute. In my final tests, the robot only averaged about 2.1 berries per minute. The main bottleneck was the linear actuator. It is cheap and strong, but it is slow. It takes about 5 seconds to extend and 5 seconds to retract. When you add the time it takes for the camera to lock onto the fruit, the cycle time is just too long to compete with a human picker right now.

Final Evaluation and What Comes Next

In my final evaluation, the AutoBerryPicker achieved a score of 73% based on my initial design requirements. It didn't meet the speed targets I hoped for, but as a proof-of-concept, it was a success. I successfully built a robot that integrates mechanical engineering, electronics, and software to find, track, and pick a fragile object autonomously.

If I were to build "Version 2.0," I would make some big changes. First, I would move away from the polar design and build an articulated arm (like a robot arm with an elbow and wrist). The maths is harder, but it would be much faster and able to reach around leaves better.

Secondly, I would redesign the gripper. The rigid parallel paddles I used were okay, but they struggled with different sized berries. Sometimes they dropped small ones, and other times they squashed big ones. A "compliant" gripper made of flexible material, or one with force sensors, would let the robot "feel" the berry and grab it with just the right amount of pressure.

Developing the AutoBerryPicker has been a massive learning experience. It showed me that solving big global problems like forced labour isn't easy, and it won't happen overnight. But it also showed me that the technology to solve these problems is within our reach. It just takes patience, a lot of testing, and the willingness to fix things when they break.

------------------------- xxxxxxxxx------------------------

Eye tracking Control Systems Applied to Wheelchairs

The current state of eye tracking systems has had tremendous development in the past few decades. Developments in AI vision have made tracking body landmarks remarkably easy, allowing eye tracking to be done accurately in a non-invasive way. However, the UI that is often used has not had as much development. Systems such as the Eyedrivomatic use a grid interface with cells connected to specific functions.

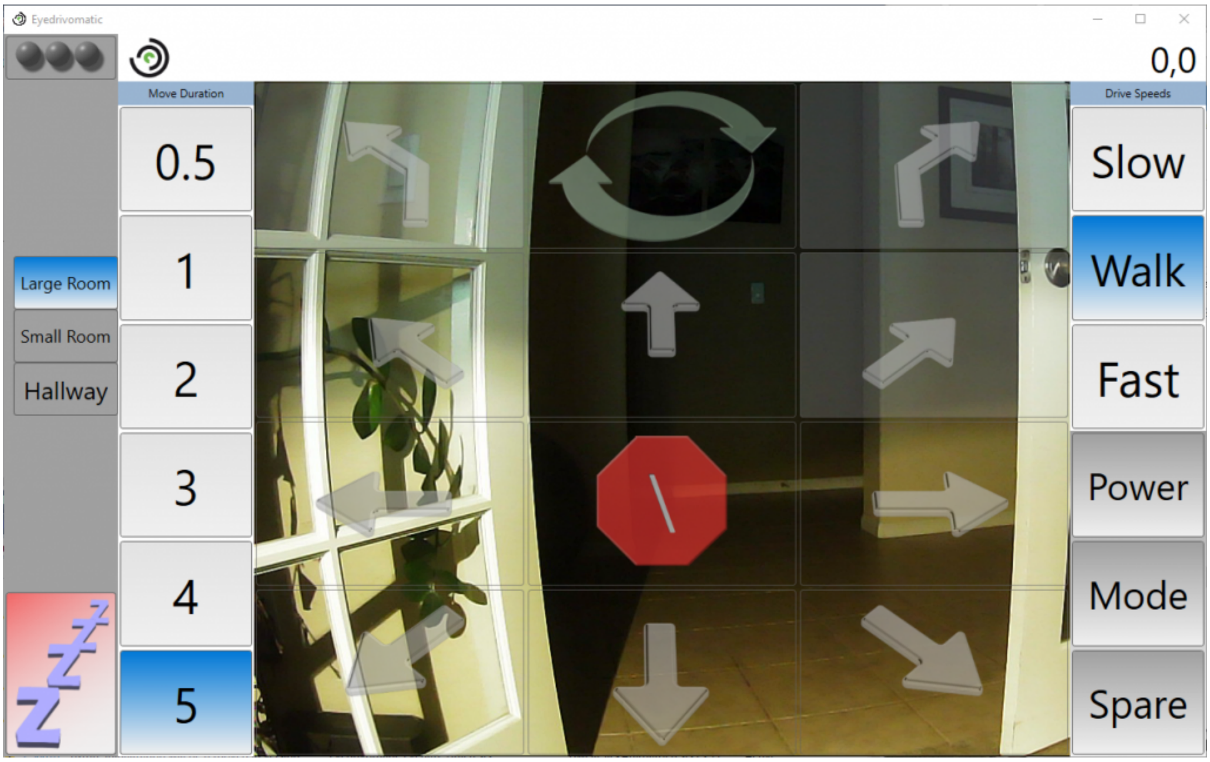


Figure 1. The user interface for the Eyedrivomatic

These button style interfaces depend on your eye acting as a mouse to move around and select different options; however your eye is also your gateway to seeing everything around you, and you either need to be focused on the screen or looking around. After talking with A/Prof Libby Callaway PhD (ARATA's Immediate Past President) about this problem I designed a new UI and a proof-of-concept wheelchair as my VCE Systems Engineering Project.

The Interface

From talking with A/Prof Callaway I was informed that the main drawback of eye gaze technology is the cognitive load that it places on the user requiring them to maintain focus at all times without deviations. The most basic action you perform when wanting to go somewhere is to look at where you want to go. This interface like many other uses AI vision to get facial landmarks. Specifically, Google's Mediapipe AI library for face landmark detection.

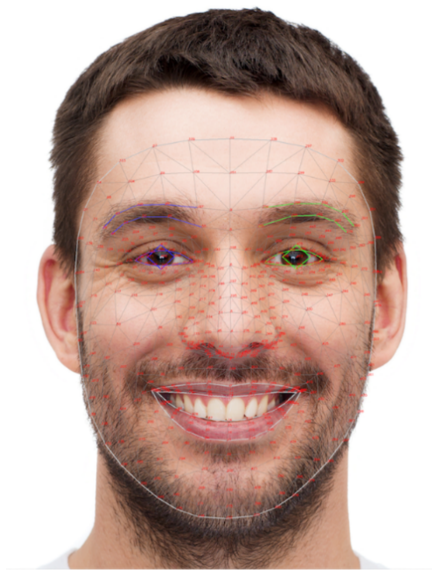


Figure 2. The landmarks given by the Mediapipe face landmark model

Using these landmarks the right and left eye can be evaluated independently and averaged to provide the best results. The pupil's centre coordinates given by point 468 for the left pupil in figure 3 can be compared to the edges of the eye given by points 33 and 133 for the left pupil giving us the horizontal deviation of the pupil.

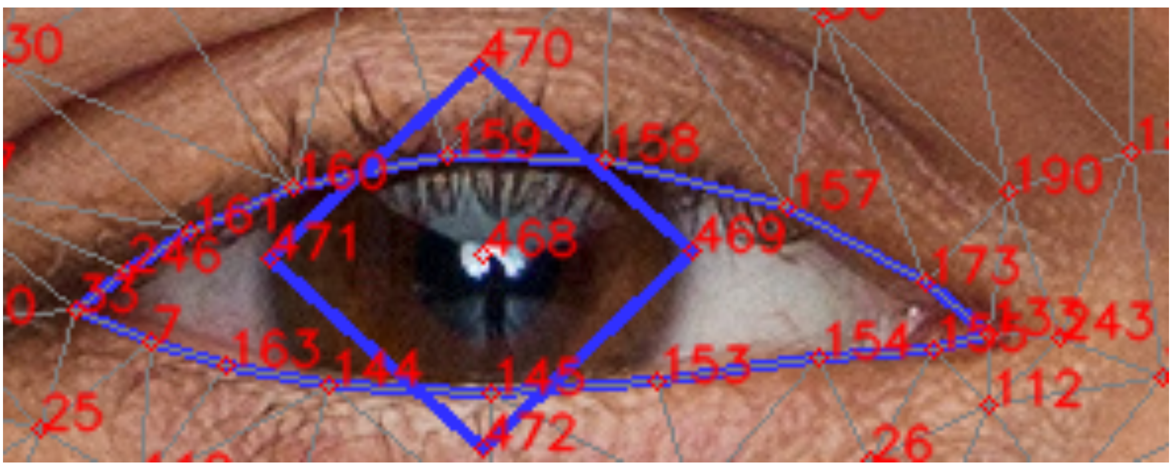


Figure 3. A close-up of the left pupils eye landmarks

Should the pupil be in the middle of the eye this indicates that the user is looking forward, thus driving forward. Should it be towards the left of right then turn more towards the left or right, with the strength of the turn indicated by how far the pupil is from the centre. The same logic can be applied to the vertical axis where should the eye be in the centre looking straight forward then set the speed to maximum. Should it be lower indicating the user is looking down on the ground then slow down the wheelchair as it is approaching the location the user is looking. However, with this approach there is nowhere to look indicating you want to stop. This can be solved by simply not looking, and by that, I mean closing your eyes. Closing your eyes is a reflexive reaction to danger to try and protect your eyes, thus making it very intuitive as a stop signal, further reducing cognitive load on the user for having to remember how to stop. To prevent blinks triggering the system a minimum closed duration needs to be configurable on the system to adjust for user preferences

To develop this UI further, interacting with the environment needs to be considered as the wheelchair cannot be moving 24/7. Instead of closing your eyes to stop, closing your eyes will act as a transition to a different operating mode. Specifically, after the drive mode there should be a stop mode, where no eye movements act as controls and the user is free to ignore the system providing concentration relief should it be needed. The logical next step would be to have the system loop back to drive mode when the user closes their eyes again, however an important control option is missing. Should there not be the space to drive forward the wheelchair needs to turn on the spot. This can be achieved by reversing the direction of one of the wheels and matching the speed of the other. Controlling this will be directly related to the pupils horizontal offset, meaning if the pupil is centred then the wheelchair will not turn. This allows for on the spot rotation as well as allowing the user to track moving targets around without moving, keeping for instance other people in view. To be as safe as possible while moving, the wheelchair control system needs to go to a stop mode after every drive mode. This can create a circular loop of control modes as shown in figure 4.

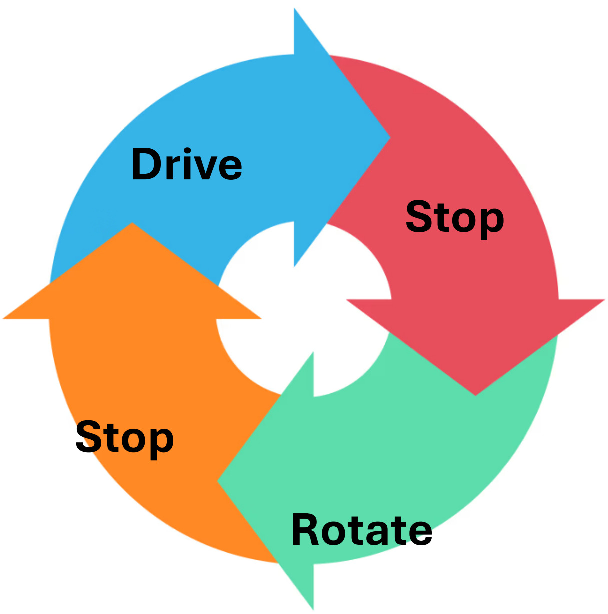


Figure 4. The 4-stage control mode loop

The Wheelchair

The wheelchair prototype to test this UI concept involved modifying a manual wheelchair to be powered, first by attaching gears to the back 2 wheels

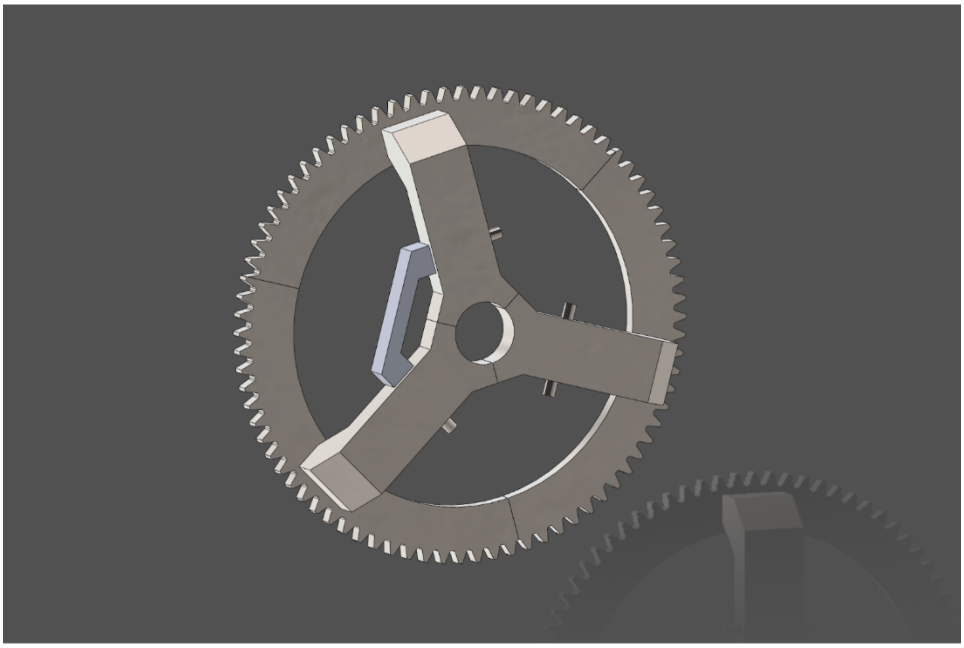


Figure 5. The wheel gear

The gear was split into 3 parts so it can be installed inside the spokes centred to axis of rotation, while the gear teeth remain accessible to the motors. Stepper motors were used due to their high torque and low speeds, as well as their good pricing, and a mount was designed and 3d printed to attach the motors to the wheelchair

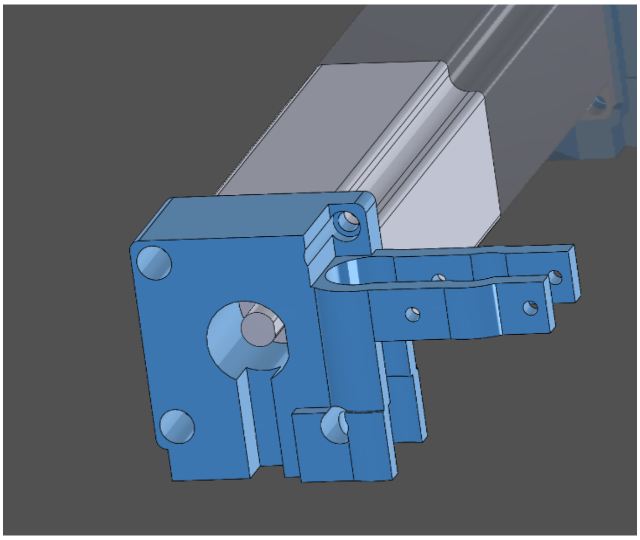


Figure 6. The stepper motor mount model

To complete the prototype stepper drivers to control the motos, an Arduino to communicate with the device running the AI Vision model, a battery to power everything and voltage regulators to keep the battery voltage stable and at a suitable output for the components were needed

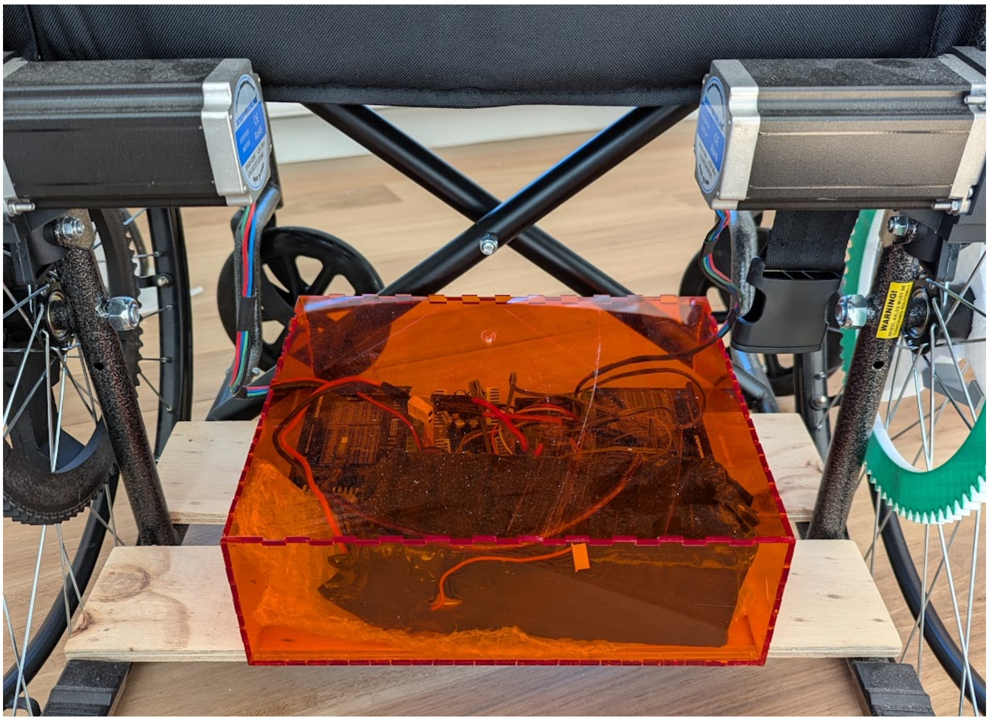


Figure 7. The electrical system of the wheelchair.

The Eye Gaze Control System proves to be an easy, intuitive, and reliable control system for eye-based inputs, and it provides a new way to interact with everyday systems.

Additional Information

Since Mediapipe has been designed to run on mobile devices it is really lightweight and efficient, meaning that other than the wheelchair modifications a phone is all that is required. However, I do not have any app development experience so for this prototype I opted to use a phone as a USB camera for my laptop, which was running the model and controlling the Arduino (The code can be found here EyeGazeControlSystem).

The prototype demo can be found here: https://www.youtube.com/shorts/Gtm9AxaAUlM
And the full documentation of the process can be found here: Full Documentation

Acknowledgements

Thanks to Dr Carlo Zino, A/Prof Libby Callaway PhD, and Michelle French for their insights and feedback to the design of the Eye Tracking Control System and Wheelchair design, and thanks to users theboot, camsysca and sterretje from the Arduino forums for their help with the Arduino-computer communication

Template for Authors

Title of the Article in English [Times New Roman, 16, Bold, Centered, Upper Case of First Letter]

Author 1 name [Times New Roman, 13, centered]
Author's Affiliation, City, Country [Times New Roman, 12, italic, centered]
Author's e-mail

Author 2 name
Author 2 affiliation, city, Country
Author 2 e-mail

Author 3 name
Author 3 affiliation, city, Country
Author 3 e-mail

Note: All Author Names are in the format of Author 1 above

Abstract
A summarized presentation of the content of the report in English. It is mandatory to use English for the title, abstract, keywords and references for proper indexing of the publication. [Times New Roman, 12, italic, justified,].

Keywords: *Science; Technology; Engineering; Art; Education; Mathematics; Innovation; Semicolon – separator of keywords [Times New Roman, 12, Italic, Justified, Upper Case of First Letter].*

Introduction (Section – Level 1 of Headings) [Times New Roman, 14, Bold Justified, Upper Case of First Letter]

All the text must be in one column [Calibri, 12, justified]. All pages should be in A4 size (21 × 29.7 cm). The top and bottom margins should be 2.5 cm and the right and left margins should be 2.5 cm.

1. METHODOLOGY

A paper should contain the description of your research and should be structured in different sections such as: Introduction, Methodology, Results, Conclusions, Acknowledgements (if applicable) and References. In particular, manuscripts should include an introductory part with representation and analysis of the problem(s) under consideration and current state-of-the-art of the existing solutions; exposition of the investigation and comments on the results obtained; evaluation of the contribution indicating advantages, limitations and possible directions for future research.

Before you offer a scientific paper for publication, make sure that: - issues about publication ethics, copyright, authorship, figure formats, data and references format have been appropriately considered:

- All authors have approved the content of the submitted manuscript;
- Manuscripts submitted to the journal should neither have been published before nor be under consideration for publication in another journal or conference.

Plagiarism in all its forms constitutes unethical publishing behavior and is unacceptable. Using AI to generate scientific text is considered a form of plagiarism. The journal uses professional plagiarism detection software.

All papers will be single-blind peer-reviewed by at least two members of the Editorial board. All submissions will be reviewed based on relevance, originality, significance, soundness, and clarity.

Formatting Instructions

Manuscripts should be written in clear and grammatically correct language. The official languages is English. The following elements must be present in English in the publication:

- Paper Title;
- Author's name(-s), affiliation(-s), country(-ies), e-mail(s);
- Abstract and keywords in English;
- References in English (transliterated into English if necessary).

Guidelines for Abbreviations and Acronyms (Subsection – Level 2 of Headings) [Times New Roman, 12, Bold, Italic, Justified, Upper Case of First Letter]

Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Do not use abbreviations in the title or headings unless they are unavoidable.

Guidelines for Figures and Tables

Figures should be centered and are numbered independently, in the sequence in which you refer to them in the text. Figure captions should be below figures, images, and graphics.

Next figure (Figure 1) is an example of a figure caption. Figure should be centered and the maximum width of the image should be 14 cm.

Figure 1. Logo of AIMERS Foundation [Calibri, 10, bold, centered, Upper Case of First Letter].

Example table (Table 1) is shown below. Table captions should be above the table. Table width is like text area – 16 cm. First row is “Headings” and repeat it at every page. Cell margins are 0.1 cm at top, bottom, left and right.

Table 1. Title of the Table [Calibri, 11, centered, Upper Case of First Letter]

	Heading 1	**Heading 2**
One [Calibri, 10, left aligned]		
Two		
Three		

Tips for making figures accessible to the blind:

- Include a description of the figure in the main text or as alternative text.
- Identify the type of image – specify the type of image (e.g., photograph, graphic, cartoon, map). Avoid vague phrases like "Image of..." - screen readers will inform users when they come across an image.
- Understand the image – before describing it, you should be clear about its purpose. If the image is purely decorative, it does not need Alt Text.
- Be concise – keep descriptions concise but informative. Overly long text can be annoying for screen reader users. Even detailed images often only need a brief description.
- Focus on key data – emphasize key data or concepts. Avoid repeating information that is already available in the surrounding text or in the figure's caption.
- Exclude irrelevant information – stick to data with scientific value. Avoid unnecessary descriptions, especially of people’s physical appearance, unless it is directly related to the topic.
- When using graphs - describe the key aspects of the information within them, not just what the graph is. Prioritize the most valuable data.

- Use an external table when displaying charts so that blind people can familiarize themselves with the data in the figure.
- Mathematical and chemical equations – describe the expression in words (spoken mathematics). Avoid symbols that screen readers might mispronounce.

Guidelines for Code

```
To write a code use Courier New font [Courier New, 10, left
aligned].
```

2. CONCLUSION

Authors should synthesize an appropriate conclusion and inferences from their research. Future plans for the development of this study can also be added.

Acknowledgements

Acknowledgements of people, grants, funds, etc. should be placed in a separate section before the reference list. The names of funding organizations should be written in full. This section is optional.

References

1. (book) A. Author, A. Author. "Book Title". City, Country: Publisher, Year.
2. (journal) A. Author, A. Author. "Article title". Journal Name, vol. number, pp. Year, DOI.
3. (website) A. Author, A. Author. "Page Title" Website Name. URL (accessed: Day-Month-Year).

Note: These are most commonly used.

MORE GUIDELINES FOR REFERENCES

Please visit:

https://apastyle.apa.org/style-grammar-guidelines/references/examples/journal-article-references

Empowering Communities Through

AI - MEDIA - EMERGING FIELDS - ROBOTICS - STEAM

About AIMERS Foundation

Mission ShakthiSAT is a global, all-female space education initiative empowering 12,000 girls from 108 countries to design, build, and operate a satellite through hands-on STEM training.Led by Space Kidz India and supported globally by AIMERS Foundation, the mission aims to create the next generation of women leaders in space, science, and technology.

Make A Mark Journal helps students learn how to explain science in a clear and meaningful way so more people can understand it. Today, when science is part of everyday life, it's important for everyone to be part of the conversation—and students can start that now.

Frustration in Science is a program that captures what people find most confusing or frustrating about science. It helps identify simple but often overlooked issues, so we can understand where the real problems are and work towards better solutions.

How Curiosity Looks is a program that helps people begin with the right questions—the ones that open the door to real understanding.Because without asking the right questions, we don't find meaningful answers or discover anything new.

Tech Can Talk is a program that helps turn complex science and technology into clear, relatable conversations for everyday people.