March 2026

GEORGIA PATHWAYS

M A G A Z I N E

Skills Students Need

Tidal Power

Tidal energy systems

Executive Skills / Mental Health

When Good Intentions Go Wrong In STEM

The Technology Association of Georgia Education Collaborative (TAG-Ed) strengthens the future workforce by providing students with relevant, hands-on STEM learning opportunities and connecting them to Technology Association of Georgia (TAG) resources.

Formerly the TAG Foundation, TAG-Ed is a 501(C)(3) non-profit organization formed by TAG in 2002. Later, the organization's name was re-branded to TAG Education Collaborative to facilitate our role as the leaders for K-12 STEM education in Georgia.

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Welcome to the March 2026 edition of Georgia Pathways Magazine, where we explore the skills, science, and innovation shaping Georgia's future workforce. This issue examines not only the technical knowledge required for tomorrow's jobs, but the cognitive foundations that enable learners to adapt and lead in an era of constant change.

As artificial intelligence continues to transform the workplace, success will depend on more than technical proficiency alone. In this issue, we explore the cognitive skills students need to thrive in an AI-driven workforce, including complex problem-solving and adaptability to ethical reasoning and sound judgment. Preparing learners for what's ahead requires intentional focus on how they think, not just what they know.

That preparation begins with understanding the science of learning itself. Our feature on executive function and mental health highlights the neuroscience behind attention, motivation, and decision-making, reminding us that effective education must account for how the brain develops and performs under pressure. Supporting students holistically strengthens both academic outcomes and long-term career readiness.

Innovation also depends on humility and evidence. In "When Good Intentions Go Wrong in STEM," we examine how progress can be undermined when enthusiasm outpaces critical evaluation. Similarly, "Do Cheetos Really Extend Your Life?" unpacks immortal time bias

in medical research, illustrating why careful data analysis is essential to advancing public health and scientific credibility.

Beyond the classroom and laboratory, this issue highlights the promise of tidal power, harnessing the natural forces of oceans and rivers to generate sustainable energy and expand the frontiers of clean innovation.

As Georgia's STEM ecosystem continues to evolve, TAG Education Collaborative remains committed to equipping learners with the skills, insight, and resilience needed to lead responsibly in a rapidly changing world. Together, we are building a future defined not only by technological advancement, but by thoughtful, informed innovation.

Larry K. Williams
President
TAG / TAG-Ed

Larry K. Williams serves as the President and CEO of the TAG and the TAG Education Collaborative. TAG-Ed's mission is to strengthen Georgia's future workforce by providing students with relevant, hands-on STEM learning opportunities by connecting Technology Association of Georgia (TAG) resources with leading STEM education initiatives.

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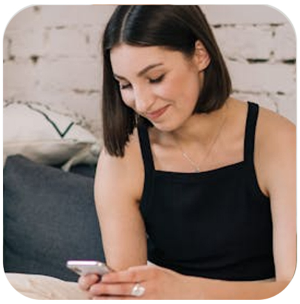
1. 

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To understand STEM...

...you must DEFINE STEM. You cannot define an acronym without defining each of the words the letters stand for.

Universities and organizations around the world continue to debate what a STEM career is, but there is no doubt that "every career" uses STEM skills and this observation remains the focus of STEM Magazine.

Science: "The systematic accumulation of knowledge" (all subjects and careers fields)

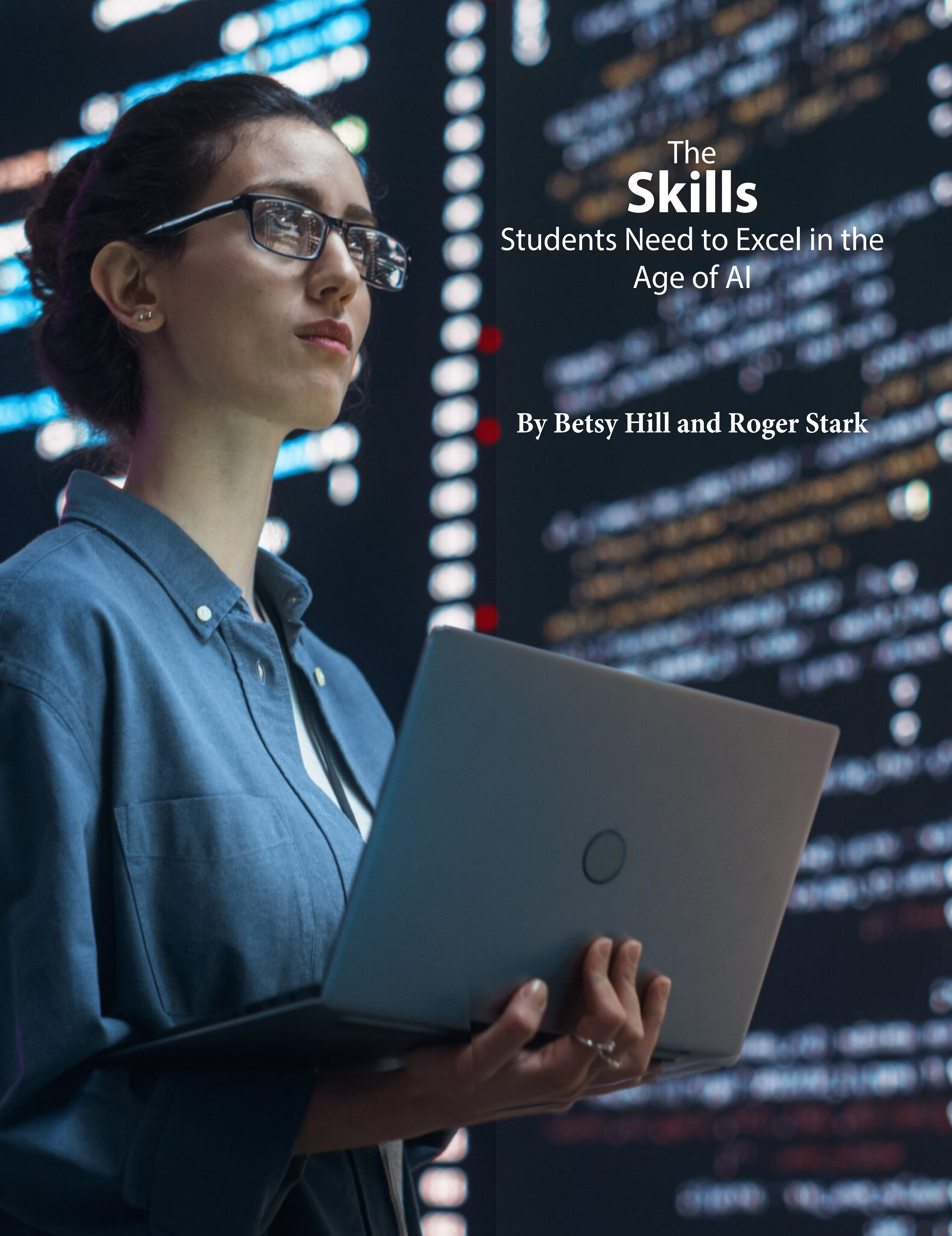
Technology: "The practical application of science" (all subjects and careers)

Engineering: "The engineering method: a step by step process of solving problems and making decisions" (every subject and career)

Math: "The science of numbers and their operations, interrelations, combinations, generalizations, and abstractions" (every career will use some form[s])

For a moment, set aside any preconceived notions of what you think a STEM career is and use the above dictionary definitions to determine the skills used in any career field you choose.

These definitions are the "real" meaning of STEM and STEM careers.



The **Skills** Students Need to Excel in the Age of AI

By Betsy Hill and Roger Stark

The AI Shift: A New Challenge for STEM Education

Artificial intelligence is transforming every field of human endeavor, and STEM disciplines are at the center of this transformation. From automated data analysis to AI-driven simulations, the tools of science, technology, engineering, and mathematics are evolving at breathtaking speed. For educators, this raises a pressing question: What skills will STEM students need to thrive in a world where AI can perform so many tasks once reserved for humans?

Predictions vary about how many jobs AI will displace — estimates range from 9% to nearly half of all roles. Yet the consensus is clear: while some jobs will disappear, nearly every job will be reshaped. For STEM fields, this means that routine calculations, standardized procedures, and even some forms of experimentation may be automated.

But the demand for higher-order cognitive skills — creativity, critical thinking, decision-making, and complex problem-solving — will grow significantly. McKinsey Global Institute projects a 19% increase in demand for these skills in the United States by 2030.

For STEM educators, the challenge is not simply to teach students how to use AI tools. It is to prepare them with the cognitive infrastructure that allows them to think with AI, challenge it, and go beyond it.

Why Human Cognition Matters More in STEM

In math and science, knowledge has always been essential. But knowledge alone is no longer enough. AI can retrieve formulas, generate proofs, and summarize scientific literature faster than any human. The real human advantage lies in making meaning — detecting relevance, weighing evidence, and reconstructing understanding when conditions change.

Making meaning is the brain's specialty, continuously adapting, integrating, and constructing knowledge. For STEM students, learning capacity is the difference between passively consuming AI-generated answers and actively shaping new discoveries. It is not a fixed trait. It rests on measurable, trainable cognitive processes in the brain.

Without strong cognitive foundations, STEM students risk becoming dependent on AI outputs they cannot evaluate. With strong cognitive foundations, they gain the ability to guide AI, challenge its assumptions, and innovate in ways machines cannot.

Cognitive Skills: The Hidden Infrastructure of STEM Success

STEM educators often focus on academic skills — algebraic reasoning, lab techniques, coding proficiency. Yet beneath these lie the cognitive skills that make academic learning possible. These are the brain's mental tools: attention, processing speed, working memory, inhibitory control, cognitive flexibility and others. They determine how effectively students can take in information, make sense of it, store it, and apply it in new contexts.

Foundational Cognitive Skills

Foundational cognitive skills include:

- **Attention:** Essential for focusing on the relevant parts of complex equations, experimental procedures, or coding tasks.

- **Processing Speed:** Determines how quickly students can handle calculations or interpret data.

- **Visual and Auditory Processing:** Critical for interpreting graphs, diagrams, and scientific explanations.

Weakness in any of these skills can make STEM learning feel overwhelming. A student who struggles with visual processing may misinterpret graphs. One with slow processing speed may fall behind in problem-solving, not because they lack understanding, but because their brain is working harder just to keep up.

Executive Functions and Executive Functioning

Educators are talking a lot about executive functioning these days – the skills students need to stay organized, get their work done and self-regulate. Executive Functions are the cognitive skills that enable executive functioning, specifically: working memory, inhibitory control, and cognitive flexibility.

These are the mental processes that regulate thinking and behavior, and they are indispensable in STEM learning.

- Working Memory allows students to hold multiple variables in mind while solving equations, track steps in a lab experiment, or compare competing hypotheses.

- Inhibitory Control helps them resist impulsive answers, pause to check calculations, and avoid cognitive biases in scientific reasoning.

- Cognitive Flexibility enables them to shift strategies when a proof fails, adapt to unexpected experimental results, or view a problem from multiple perspectives.

Together, these functions are the gateway to higher-order skills: planning, organization, communication, adaptability, critical thinking, creativity, innovation, and decision-making. In STEM contexts, these are not optional extras. They are the very skills that distinguish human scientists, engineers, and mathematicians from machines.

Executive Functions in Action: STEM Examples

- **Planning in Engineering:** Working memory keeps design constraints in mind, inhibitory control prevents skipping safety checks, and cognitive flexibility allows redesign when prototypes fail.

- **Organization in Mathematics:** Working memory tracks multiple steps in a proof, inhibitory control resists careless shortcuts, and cognitive flexibility adjusts methods when an approach stalls.

- **Communication in Science:** Working memory tracks the flow of an argument, inhibitory control tempers emotional reactions to peer review, and cognitive flexibility adapts explanations for different audiences.

- **Critical Thinking in Data Science:** Working memory holds evidence and counterarguments, inhibitory control resists bias, and cognitive flexibility shifts between statistical, ethical, and practical frameworks.

These examples illustrate why Executive Functions are not just about classroom behavior. They are the cognitive core of STEM thinking.

The Risk of Cognitive Debt in STEM Education

Recent research highlights a troubling trend; over-reliance on AI tools can reduce cognitive activation. In one study, college students who used large language models to write essays produced more homogeneous work and showed reduced neural activation compared to those who relied on their own brains.

For STEM students, this raises a critical concern: if AI shortcuts suppress originality and weaken executive function, how will they develop the creativity and critical thinking needed for scientific discovery?

The danger is cognitive debt — a deficit in the brain's learning systems caused by outsourcing too much thinking to machines. For STEM fields, where innovation depends on flexible, resilient cognition, this debt could be catastrophic.

Developing Cognitive Skills: A New Imperative for STEM Educators

Traditionally, schools have assumed that students arrive with the cognitive skills they need, or that these skills improve automatically through academic work. Neuroscience tells a different story: cognitive skills are trainable. When strengthened, they increase a learner's capacity to understand, remember, and apply academic content. But they must be trained, not explained.

Comprehensive Integrated Cognitive Training (CICT®)

CICT is a method that strengthens multiple cognitive skills simultaneously:

- Integrated: Targets attention, memory, reasoning, and executive functions together.
- Sequential and Adaptive: Challenges learners at the edge of their ability to drive neural growth.
- Designed for Transfer: Improvements carry over to academics and everyday tasks.
- Sustainable: Gains are measurable and long-lasting with sufficient frequency and intensity.

At Maple Crest STEM Middle School in Indiana, students with strong reasoning but weak Executive Functions participated in CICT. Before training, they struggled academically not because they lacked understanding, but because their brains could not efficiently hold, organize, and apply information. After thirty sessions, their executive function scores rose significantly, and their nonverbal reasoning improved beyond already high levels.

The principal observed "astronomical growth" in both ability and confidence. For STEM educators, this is a powerful lesson: strengthening cognitive skills is not a luxury. It is a prerequisite for preparing students to excel in math and science in the age of AI.

Building Future-Proof STEM Skills

AI accelerates information and automates routine work, but it cannot understand meaning, weigh values, or learn from experience. For STEM students, the most important capability is no longer how much they know, but how effectively they can learn. This requires intentional development of:

- Cognitive Architecture: The brain's learning systems — attention, processing speed, memory.
- Executive Functions: Regulation of thinking — working memory, inhibitory control, cognitive flexibility.
- Higher-Order Skills: Application of knowledge in new contexts — critical thinking, creativity, innovation.

When STEM educators focus on these foundations, they do more than improve test scores. They prepare students to keep learning long after graduation, to adapt to new technologies, and to lead in fields where knowledge doubles faster than ever.

Practical Steps for STEM Classrooms

How can math and science educators integrate cognitive skill development into their teaching?

1. Embed Cognitive Challenges in Lessons
- Use multi-step problems that stretch working memory.
- Incorporate tasks that require shifting perspectives, such as analyzing data from different models.

2. Teach Students to Pause and Reflect
- Encourage inhibitory control by building "pause points" into problem-solving.
- Model how to resist cognitive biases in scientific reasoning.

3. Foster Flexible Thinking
- Present problems with multiple solution paths.
- Use interdisciplinary projects that require shifting between scientific, mathematical, and ethical frameworks.

4. Integrate Cognitive Training Tools
- Explore digital platforms that deliver CICT exercises.
- Use short, daily cognitive workouts alongside academic instruction.

5. Assess Cognitive Skills Directly
- Move beyond testing only content knowledge.
- Include measures of attention, memory, and executive functions to identify students who need support.

Conclusion: Preparing STEM Students for the AI Future

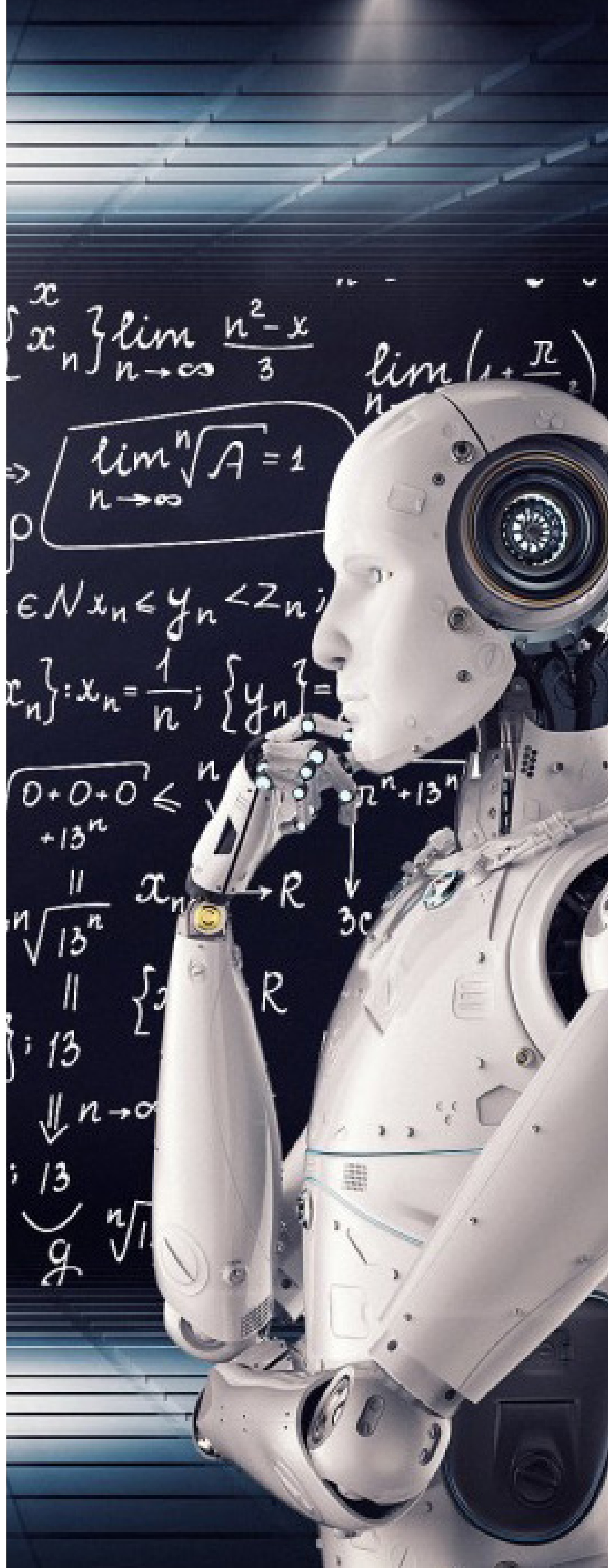
AI is reshaping the landscape of STEM education. But the most important skills for STEM students are not technical proficiency alone. They are the cognitive capacities that allow students to learn deeply, think critically, and innovate continuously.

Knowledge will always matter, but in a world where AI can retrieve information instantly, the true differentiator is how effectively students can use knowledge, adapt to change, and construct new understanding.

For math and science educators, this means shifting focus from content delivery alone to intentional development of cognitive skills and executive functions. By embedding cognitive challenges in lessons, fostering flexible thinking, and integrating training methods like Comprehensive Integrated Cognitive Training (CICT), educators can help students build the mental infrastructure that makes STEM learning resilient and future-proof.

AI can accelerate thinking — but only if the learner has the cognitive strength to steer it. Without that, AI becomes a shortcut that leads to shallow understanding and dependence. With it, STEM students gain the ability to guide AI, challenge its outputs, and expand what is possible in science, technology, engineering, and mathematics.

The future of STEM belongs to those who can learn — deeply, flexibly, and continuously. By cultivating cognitive skills alongside academic knowledge, educators can ensure that their students are prepared not just to survive in the age of AI, but to lead it.



Executive Skills *ARE* Mental Health Skills

A Neuroscience-Informed Strategy for Healthier Students and Stronger Schools

By Samantha Woods
Founder of Kaizen Education Services & The Brain Hub Academy

When I shared that my 20-year-old son was recently diagnosed with ADHD, the reaction from friends was disbelief. "Not him! He's calm, polite, and smart!" As an educator and researcher who's spent decades working with neurodivergent learners, I shouldn't have been surprised - but I was. The stigma around ADHD still runs deep, as does the misunderstanding of what it truly is.

This moment reminded me: our systems still treat attention and regulation challenges as behavioural problems instead of recognizing them as executive function (EF) delays. It's time to change that narrative. EF training isn't just academic support, it's mental health support.

The Mental Health Crisis Behind the Classroom Walls

Educators and school psychologists are seeing a surge in student anxiety, avoidance, and emotional dysregulation. Yet many of these challenges are not simply social-emotional; they are rooted in lagging executive skills like emotional control, organization, and impulse regulation. Skills that are teachable.

Imagine if we stopped treating EF skills training as a niche support strategy for diagnosed students and started seeing it as an essential component of every school's academic curriculum and mental health framework?

ADHD and Executive Functioning: What We're Missing

Despite increased awareness of ADHD, misconceptions persist. ADHD is not a deficit of attention; it's difficulty managing attention. As Dr. Hallowell and Dr. Ratey explain, people with ADHD often have too much attention, scattered across competing stimuli. What they lack is executive control over that attention.

These are executive skills - planning, emotional regulation, task initiation, and working memory- and in people with ADHD, they are often underdeveloped. According to the National Institute of Mental Health, ADHD affects 4.4% of adults and up to 8.1% of U.S. adults aged 18 to 44. In children, it's even more common.

But the issue isn't just prevalence, it's impact. Without support to build EF skills, children with ADHD (and many without formal diagnoses) face higher risk of anxiety, depression, poor academic outcomes, and low self-worth. The gap isn't in intelligence, it's in brain-based skills.

Executive Functioning = Resilience, Regulation, and Mental Health

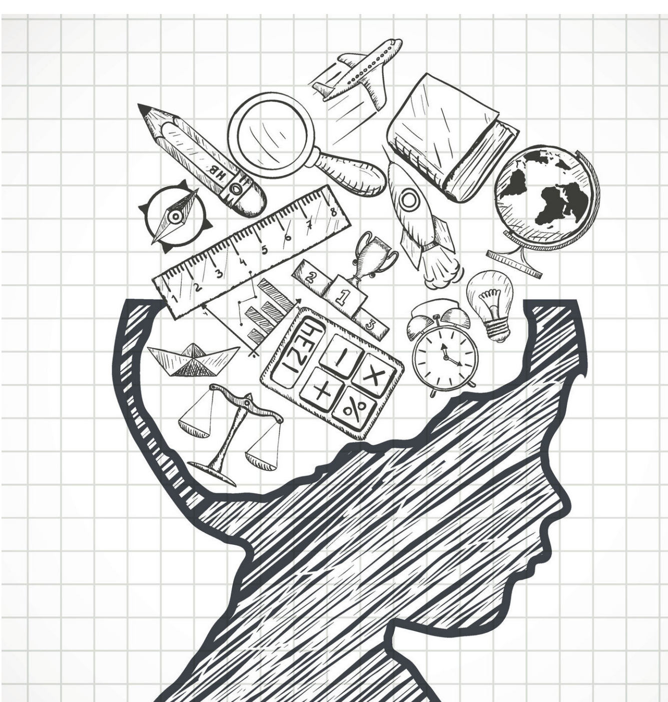
Executive functions are the brain's self-management system. They allow us to plan, organize, remember, adapt, and regulate. They also lay the groundwork for emotional wellbeing. As New Zealand's Koi Tū: The Centre for Informed Futures notes:

"Executive functions promote psychological resilience and protect against the effects of stressful events that impact mental health."

In simple terms, EF skills help children:

- Navigate social situations
- Tolerate frustration
- Transition between tasks
- Cope with stress
- Set and achieve goals
- Ask for help when needed

Students lacking these skills are often misinterpreted as unmotivated, defiant, or lazy. In truth, they're overwhelmed. These deficits, when left unaddressed, create what I call the "behaviour-skills-mental health triangle"-



a cycle of misinterpreted behaviour, missed support, and declining mental health.

EF skills don't emerge fully formed; they are developmental and malleable, which is why adolescence is a critical intervention window. As students' brains continue to mature into their twenties, they need coaching in self-awareness, emotional regulation, and executive functioning.

The Research: Executive Skills Predict Lifelong Wellbeing

The evidence is clear. In Executive Functions: A Crucial but Overlooked Factor for Lifelong Wellbeing (Low, Gluckman & Poulton, 2021), researchers link EF development to:

- Education: Poor EF predicts school failure. Students with weak EF are less likely to complete formal education, affecting job prospects and earning potential.

- Mental health: EF deficits increase the risk of anxiety, depression, and oppositional behaviour. Chronic stress worsens EF, forming a vicious cycle.

- Employment: Adults with poor EF experience more job instability and lower productivity.

- Health: Weak EF is associated with obesity, substance abuse, and non-adherence to treatment regimens.

- Parenting: Adults with poor EF often struggle with consistent parenting, perpetuating intergenerational disadvantage.

Strong EF is also linked to slower biological aging, greater resilience, and increased life satisfaction. These aren't just school skills. They're life skills.

Evidence-Based EF Programs Are Working

Global studies confirm that executive functioning can be taught, with wide-ranging benefits:

- Improved emotional understanding and reduced aggression.

- Strengthened cognitive flexibility and reduced behavioural outbursts.

- Increased attention and working memory.

- Greater independence of student organization, time management, and stress tolerance.

Research by Diamond (2016) and Blair & Raver (2014) shows that EF-focused programs improve emotional resilience, reduce mental health referrals, and strengthen academic outcomes. Mindfulness-based approaches, often embedded in EF training, further support emotional regulation, especially in students with trauma backgrounds.

It's not just students who benefit. Teachers trained in EF strategies report lower burnout and greater job satisfaction (Miller et al., 2017; Schonert-Reichl, 2017). When teachers understand the brain-based "why" behind student behaviour, their responses become less reactive and more supportive, improving outcomes for everyone.

Skills Before Symptoms: A Preventative Mental Health Approach

What if we stopped waiting for breakdowns and taught the skills to prevent them? Executive function training isn't a luxury, it's upstream prevention. It reduces the need for high-cost, reactive interventions by addressing root causes. This proactive shift includes:

- Integrating EF strategies into daily classroom routines.
- Offering quality professional learning for all educators.
- Providing families with practical tools and language.
- Empowering students to understand and manage their own brains.
- Replacing outdated curricula with relevant executive skills-training programs.

Programs like The Brain Hub Academy are already delivering EF training to students, educators, and families in accessible, neuroscience-informed ways. Though not a replacement for therapy, these resources build foundational layers of brain health and wellbeing, self-awareness, and academic skill development essential to personal and academic success.

From the Classroom to the Boardroom: Averting Future Mental Health Crises

"With access to quality executive functioning programs, students facing EF challenges can build the skills they need to thrive, transforming futures and preventing crises before they begin."

The long-term stakes are significant. The Dunedin Study (2016) found that just 20% of individuals with weak EF and early adversity account for nearly 80% of adult social and financial costs, including incarceration, chronic illness, unemployment, and reliance on public services. If we want to disrupt these cycles of disadvantage, we must start with brain-based skills…and we must start early.

This isn't about adding more to teachers' jobs. It's about modernizing the curriculum, replacing outdated mandates with neuroscience-informed instruction that builds capacity for learning, regulation, and adaptation.

Executive function training isn't extra. It's essential. Mental health doesn't start with a referral. It starts with a student learning how to pause, reflect, organize, and reset. That's the power of EF training.

Final Thoughts

Executive functioning is not a trend. It's the science of how we learn, behave, and thrive. It is the foundation of mental health, and it belongs in every school.

If we want to support struggling learners, reduce burnout, and create sustainable wellbeing from childhood into adulthood, we need to prioritize the one skill set that supports them all.

We start with the brain. We start with executive functioning.

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Samantha Woods is a veteran educator, executive functioning coach, and founder of The Brain Hub Academy and Kaizen Education Services. She is known for her neuroscience-informed approach to skill-building in classrooms, boardrooms, and family rooms and her passionate advocacy for workplaces and schools to embrace neurodiversity using science-backed strategies. With 30+ years of experience, she translates neuroscience into practical tools that boost focus, productivity, and well-being.

As founder of Kaizen Education Services and creator of The Brain Hub Academy, Samantha empowers educators and employers to build critical executive skills like attention, planning, and emotional regulation—skills essential for success but often overlooked. Backed by the latest brain research, Samantha helps teams build inclusive, high-functioning environments where all brains can thrive.

Follow Samantha and Kaizen on Instagram, Facebook, LinkedIn, or drop by her website to learn about the Brain Hub Academy Executive Skills Training Program for Educators and Parents.

Tidal Power

by Dr. Carl Peterson

A tidal turbine weighing 680 metric tons and dubbed "the world's most powerful" has started grid-
European Marine Energy Centre in Orkney, an archipelago located north of mainland Scotland.

The gravitational pull of the moon and sun along with the rotation of the earth create tides in the oceans. In some places, tides cause water levels near the shore to rise and fall up to 40 feet. People in Europe harnessed this movement of water to operate grain mills more than a 1,000 years ago.

-connected power generation at the

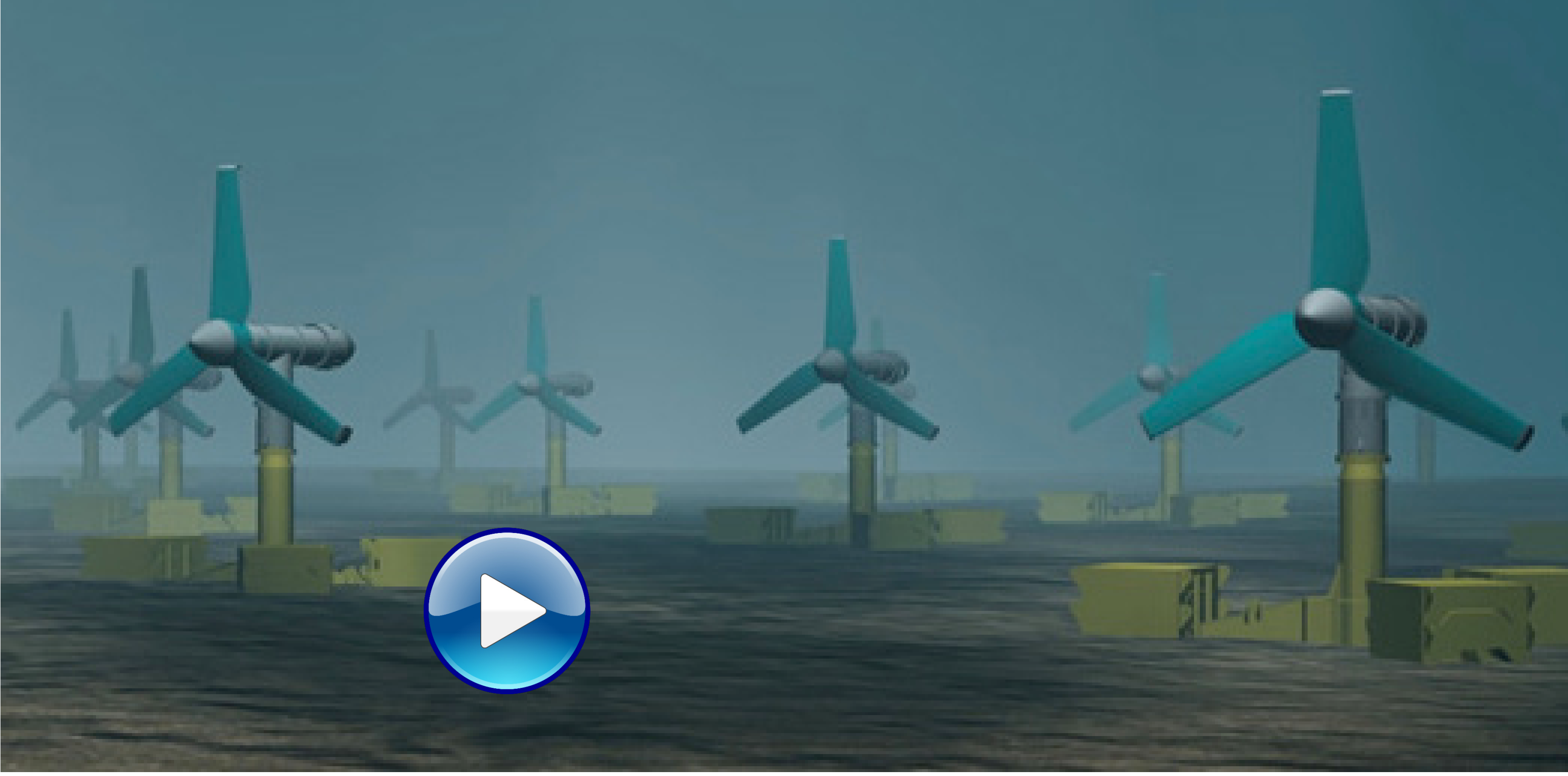
Audio Version

Today, there are tidal energy systems that generate electricity producing tidal energy economically within the required tidal range of at least 10 feet.

There are a number of ways in which tidal power can be harnessed. Tidal barrage power systems take advantage of differences between high tides and low tides by using a “barrage,” or type of dam, to block receding water during ebb periods. At low tide, water behind the barrage is released, and the water passes through a turbine that generates electricity. Tidal stream power systems are used around islands or coasts where these currents are fast. They can be installed as tidal fences where turbines are stretched across a channel or as tidal turbines, which resemble underwater wind turbines.

The total energy contained in tides worldwide is 3,000 gigawatts (GW; billion watts). By comparison, a typical new coal-based generating plant produces about 550 megawatts (MW; million watts).

Although total global electricity consumption approached 21,000 terawatt-hours in 2016 (one terawatt [TW] = one trillion watts), energy experts speculate that fully built-out tidal power systems could supply much of this demand in the future.



Estimates of tidal stream power—which uses ocean currents to drive underwater blades in a manner similar to wind power generation—in shallow water is capable of generating some 3,800 terawatt-hours per year.

Environmental concerns raised about tidal power stations are largely focused on the tidal barrage systems, which can disrupt estuarine ecosystems during their construction and operation. Tidal fences and turbines are expected to have minimal impact on ocean ecosystems. Tidal fences do have the potential to injure or kill migratory fish, however, but these structures can be designed to minimize such effects.

Tidal power leverages the rise and fall of oceanic tides to capture potential or

kinetic energy and convert it into other energy forms, often electricity. There are two methods of harnessing tidal power. One method resembles a hydroelectric dam, called tidal barrages, and another relies on underwater turbines that have blades that rotate as water flows by, powering a generator in the process.

Tidal turbines may be installed in water sources ranging from areas with strong ocean currents to tidal streams and estuaries. They may be installed on their own, but larger energy projects commonly install connected rows of turbines, called an array. Variations in wind patterns, weather, and turbulence make it inherently challenging to predict while the benefit of tidal power is its relatively high power output. Because water is roughly 830 times denser than air, tidal or ocean currents can generate more energy per unit area than winds.

Despite these advantages and the skyrocketing demand for clean, renewable energy, tidal power hasn't taken off in the same way that solar and wind energy have. There are only a handful of commercially-operating tidal power plants worldwide, the largest of which is the Sihwa Lake Tidal Power Station in South Korea.

"The fundamental question is one of economics," says Brian Polagye, Associate Professor of Mechanical Engineering and Director of the Pacific Marine Energy Center at the University of Washington. Because of the early stage of the technology, tidal power is an expensive source of energy: according to a 2021 study, commercial-scale tidal energy is estimated to cost $130-$280 per megawatt-hour compared to $20 per megawatt-hour for winds.

High upfront costs of building plants, expenses associated with maintaining machinery that can survive corrosive seawater, and the costly engineering work that goes into them make up a significant portion of that cost challenges. Much of the current manufacturing efforts associated with wind and solar power use hardware and tech that do not work in an underwater environment, so we would have to start fresh manufacturing those physical parts.

The future

Tidal power is thriving in some countries. In Scotland, a 600-ton turbine anchored right off of the Orkney Islands is already generating power. The turbine, named the O2, is projected to meet the energy demands of 2,000 homes for the next 15 years. Recently, the UK also introduced a new set of incentives that specifically support tidal energy.

The United States is rapidly developing its offshore wind industry, targeting 30,000 megawatts by 2030, with major projects concentrated on the East Coast and emerging plans for the Pacific. Key, active projects include the Coastal Virginia Offshore Wind (CVOW) ($11 billion, 176 turbines) and Vineyard Wind. While most current projects use fixed-bottom foundations, California is planning for large-scale floating turbines.

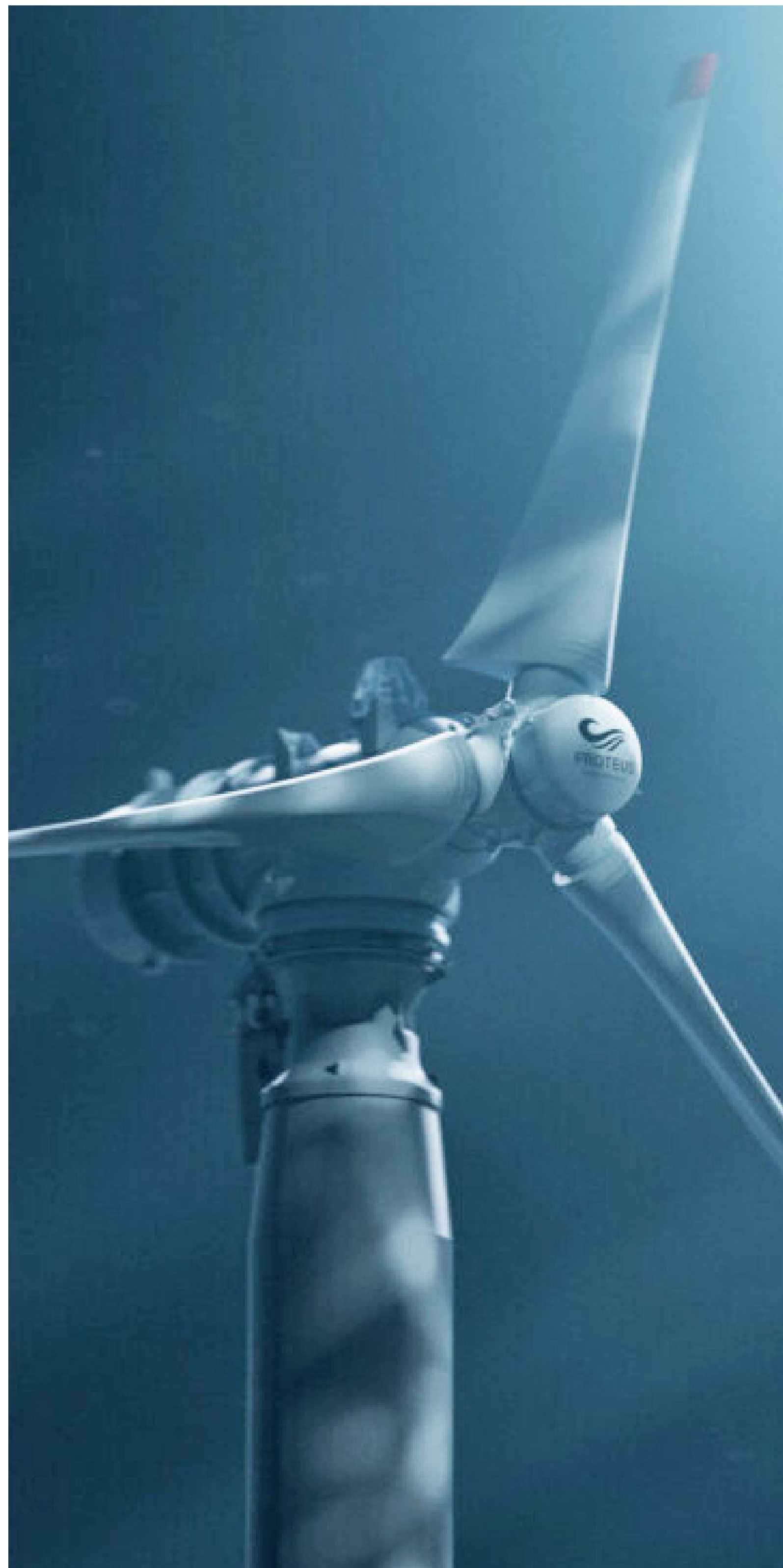
A turbine at the MeyGen site in northern Scotland has been generating electricity underwater for 6.5 years without unplanned maintenance, demonstrating long-term durability in harsh marine conditions.

The site includes four turbines generating 1.5 megawatts each, enough to power about 7,000 homes annually, and plans are underway to expand to 130 higher-output turbines. Experts say the milestone may ease investor concerns about maintenance challenges, though regulatory hurdles, environmental impacts, and space conflicts still limit wider adoption.

"I think they have checked the boxes. Because skeptics, and that includes investors of course and governments, said, 'How on Earth are you going to operate these things especially for any length of time in this very tough environment?' And that's what I think they proved." — Andrea Copping, distinguished faculty fellow, School of Marine and Environmental Affairs at the University of Washington

Why this matters:

Tidal energy offers a steady, predictable source of clean power, unlike wind and solar, which fluctuate with weather. The ocean holds massive untapped energy potential, but converting that energy into electricity at scale has long been a technical and financial challenge. Saltwater corrodes metal, marine debris can jam machinery, and underwater maintenance is expensive. Demonstrating that turbines can last more than six years without disruption is a major step toward scaling the technology.



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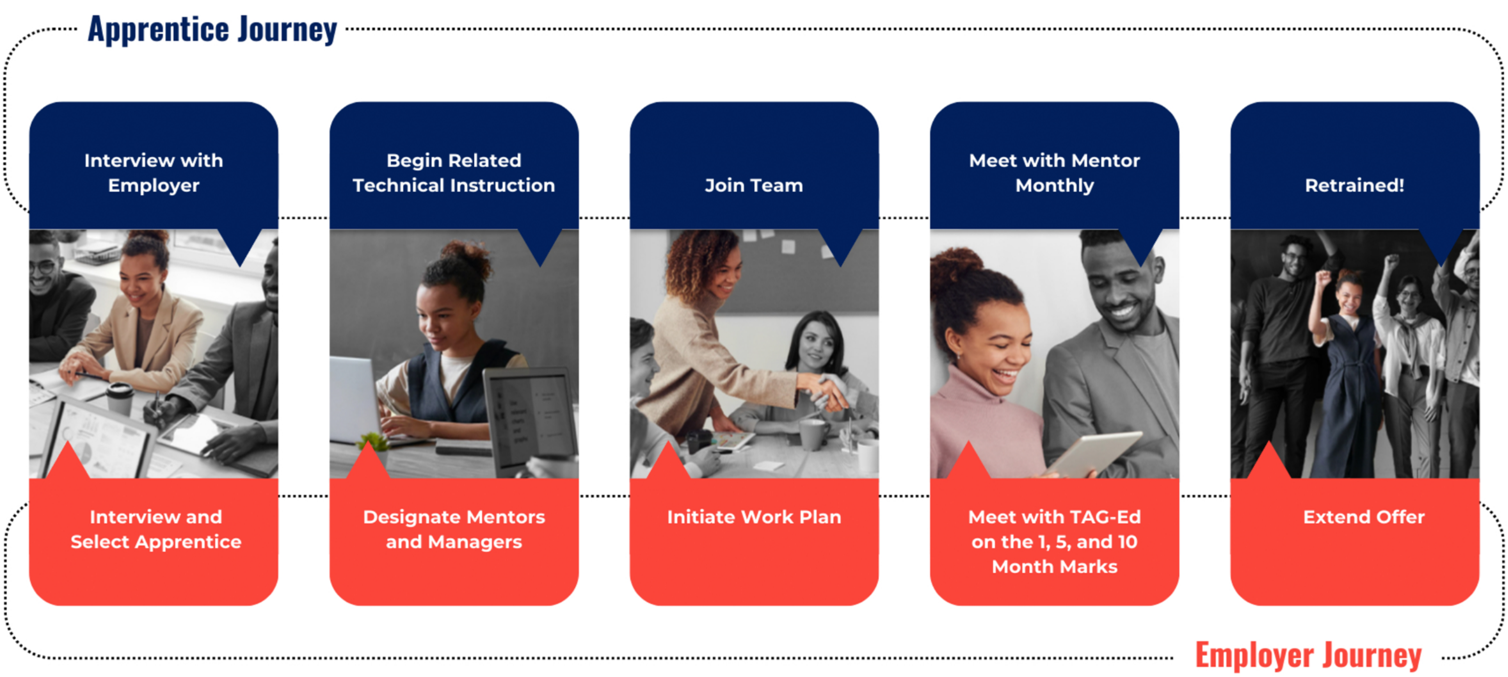

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When Good Intentions Go Wrong in STEM

Why Benevolence Without Humility Can Undermine Science, Education, and Innovation

By Shelly A. Muñoz

STEM fields are often associated with progress, problem-solving, and the pursuit of good. From medical breakthroughs to educational innovation, much of what happens in science, technology, engineering, and math is driven by a desire to help, to improve lives, systems, and futures.

> ***"Good intentions do not make an idea safe. In STEM, care must be paired with curiosity, humility, and the courage to keep asking hard questions."***
>
> - Shelly A. Muñoz

Yet psychologist Jordan Peterson offers a caution that is deeply relevant to STEM communities. Evil does not usually appear as malice. It often arrives disguised as benevolence.
In STEM contexts, this warning is not abstract. It shows up wherever good intentions override inquiry, humility, and accountability.

Benevolence is not the same as wisdom. In science, intention does not determine truth. Evidence does. History reminds us that harm has occurred when researchers, policymakers, or educators believed their goals were unquestionably good and therefore beyond scrutiny. In each case, the motivation sounded compassionate. The failure came when moral certainty replaced critical evaluation. STEM advances when assumptions are challenged, not when they are protected.
In engineering and technology, innovation thrives on iteration. Designs are tested, they fail, they improve, and they evolve. Problems arise when systems are treated as morally perfect rather than experimentally provisional.

When benevolence becomes controlled, feedback is dismissed instead of welcomed. Failure is hidden rather than studied. Dissent is framed as obstruction. Healthy STEM culture treats disagreement as data. Language such as "we know what's best," "the science is settled," or "questioning this causes harm" can quietly shut down the very practices that make STEM trustworthy. Questioning, testing, peer review, and revision are not obstacles to progress. They are the foundation of it. Progress depends not on certainty, but on intellectual humility.

STEM history offers sobering lessons. Some of the most troubling scientific failures were fueled by benevolence without restraint. Research has been conducted for the greater good without consent. Technologies have been deployed before ethical implications were understood. Educational reforms have been implemented without listening to learners or communities.

This dynamic is especially visible in STEM education. The desire to protect students from discomfort can unintentionally weaken learning. Real scientific understanding requires cognitive struggle, failure and revision, exposure to uncertainty, and productive disagreement.

When discomfort is confused with harm, students lose opportunities to develop resilience, critical thinking,

Intellectual humility is the recognition that one's beliefs, knowledge, and viewpoints may be incomplete, flawed, or wrong. It involves a non-threatening awareness of one's own cognitive limitations, a willingness to revise opinions in light of new evidence, and the ability to keep one's ego in check during disagreements. It is a balanced, virtuous approach to learning that avoids both intellectual arrogance and excessive self-doubt.

and scientific literacy. Care in education does not remove challenge. It guides learners through it.

Ethical STEM practice requires ongoing self-examination. Good intentions are not enough. Responsible innovation asks who might be affected in unintended ways, what voices are missing, and what evidence would cause us to revise our approach. Benevolence becomes dangerous when it resists these questions.

Warning signs appear when questioning is treated as dangerous, when morality replaces evidence, when critique is rejected, when complex systems are oversimplified, and when urgency is prioritized over accuracy.

By contrast, healthy STEM culture values curiosity over certainty, evidence over intention, iteration over perfection, dialogue over dominance, and responsibility over righteousness.

This matters now more than ever. In an era of rapid technological change, artificial intelligence development, data-driven decision-making, and large-scale educational reform, STEM professionals wield enormous influence. With that influence comes responsibility not just to innovate, but to remain humble.

The most reliable safeguard against harm is not better intentions, but better processes. Transparent inquiry. Open debate. Ethical restraint. Willingness to change course.

"Progress that cannot tolerate questions is not progress at all. The future depends on our willingness to remain curious, even when certainty feels more comfortable." — Shelly A. Muñoz

The strength of STEM has never been moral certainty. It has always been the courage to ask what if we are wrong. When benevolence is paired with humility, science advances responsibly. When benevolence stands alone, unchecked by critique, even the best intentions can mislead.

In STEM, as in life, goodness is proven not by how right we feel, but by how carefully we listen, test, and revise.

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Do Cheetos Really Extend Your Life?

Immortal Time Bias and Target Trial Emulation Explained

By Rajsumeet Macwan, PharmD, Class of 2025, Anastasiya Shor, PharmD, BCPS, Connor Orlowski, PharmD

In 2019, researchers published a study analyzing data from 19,811 patients hospitalized for asthma In 2019, researchers published a study analyzing data from 19,811 patients hospitalized for asthma exacerbations treated with corticosteroids across 542 U.S. acute care hospitals participating in the Premier Inpatient Database.

The observational study defined the treatment group as patients who started antibiotics within the first 2 days and continued antibiotics for at least 2 days. The control group was defined as patients who did not receive antibiotics during the first 2 days or who started antibiotics after day 2.

Initially, the study concluded that patients treated with antibiotics had significantly longer hospital stays. However, these conclusions were soon challenged and eventually retracted due to a statistical error known as immortal time bias—a subtle but crucial error that can profoundly mislead interpretations about treatment effectiveness.[1]

To understand immortal time bias, consider a humorous yet insightful analogy involving Cheetos. Imagine researchers trying to determine if eating Cheetos, the popular corn-cheese snack, improves survival in patients hospitalized with myocardial infarction (MI). Every patient presenting with an MI receives an unopened bag of Cheetos, which they can eat at any point during their hospital stay. Patients who survive long enough get the chance to eat them are classified under Cheetos group.

Whereas those who die early are automatically labeled as not having consumed the snack. Assigning individuals to a treatment arm based on the treatment they receive after time zero introduces immortal time bias. During this span of time the outcome of interest could not have occurred. Thus, a naive analysis might falsely suggest that consuming Cheetos significantly enhances survival simply because only survivors had the opportunity to eat them.[2]

This analogy mirrors the original researchers' error of including patients who received antibiotics only after surviving long enough into their hospital stay. When researchers corrected the analysis to compare patients who received antibiotics on the first day of hospitalization versus those who did not, results shifted dramatically.

The revised data showed only a marginally longer hospital stay (mean 2.81 days vs. 2.57 days, difference of 0.11 days; 95% CI, 0.03 to 0.19). While the results were statistically significant, they are not clinically meaningful. These corrected findings underscore the importance of immortal time bias in observational research.

What is Immortal Time Bias?

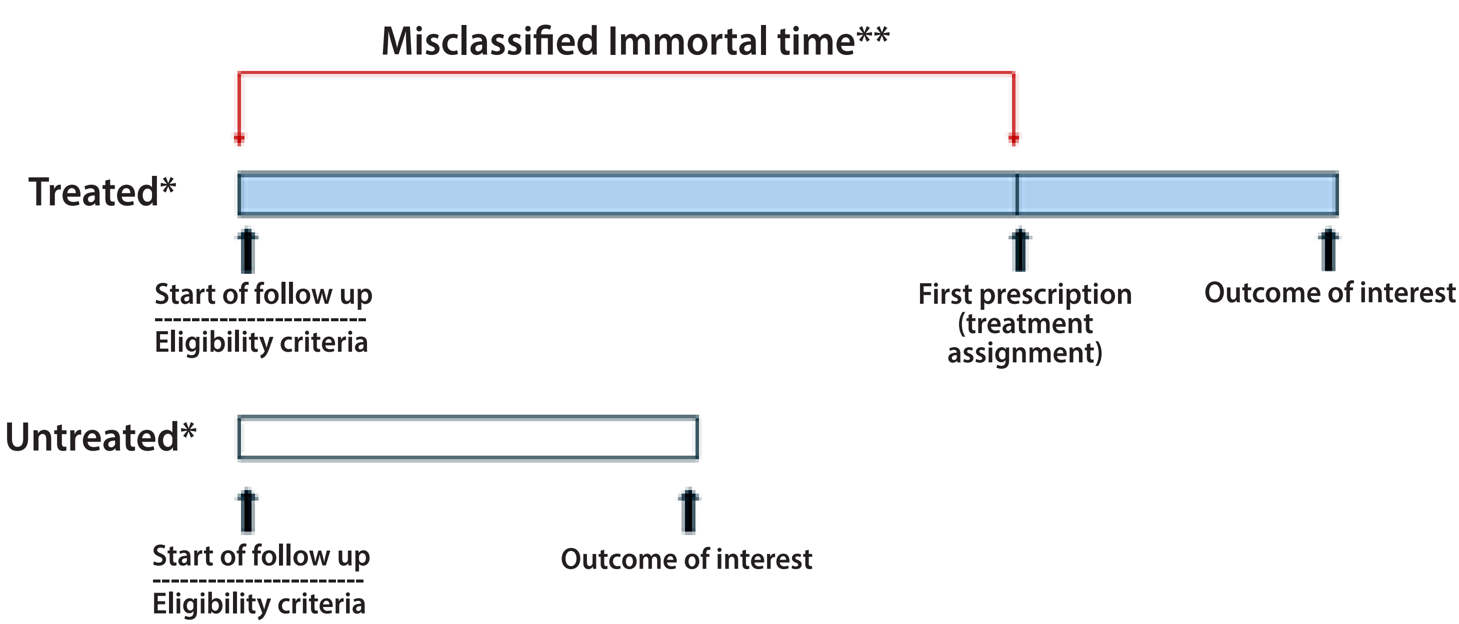
Immortal time refers to a period during which the outcome of interest cannot occur. During this "immortal" time, individuals (often in the treatment group) are effectively immune to the outcome by design, which can

falsely suggest that a treatment is protective. Study subjects are not truly immune to the outcome but appear as if they are, due to a flaw in the study design.[3]

Immortal time bias arises when time zero is not properly specified as the point where follow-up begins, eligibility criteria are met, and treatment is assigned.[4] In randomized controlled trials, all three components are aligned at the time of randomization. However, in observational studies, these elements may not align, resulting in immortal time bias either due to misclassification of assignment or selection bias.

Classic immortal time bias can occur when treatment strategies are misclassified based on treatments received after eligibility and the start of follow-up, especially if the treatment strategies cannot be clearly distinguished at time zero.[5] For instance, if a study is conducted to examine the effects of a drug post-discharge compared to no treatment, immortal time bias can arise if there is a delay between a participant's entry into the study and the time they receive their first treatment, such as filling a prescription.[6]

During this follow-up period, participants must remain alive and event-free to be classified as treated, effectively contributing to immortal time in the exposed group (Figure 1).Since these participants cannot experience the outcome during this period, a misleading



*Patients in the treated group must survive until the first prescription created survival advantage.

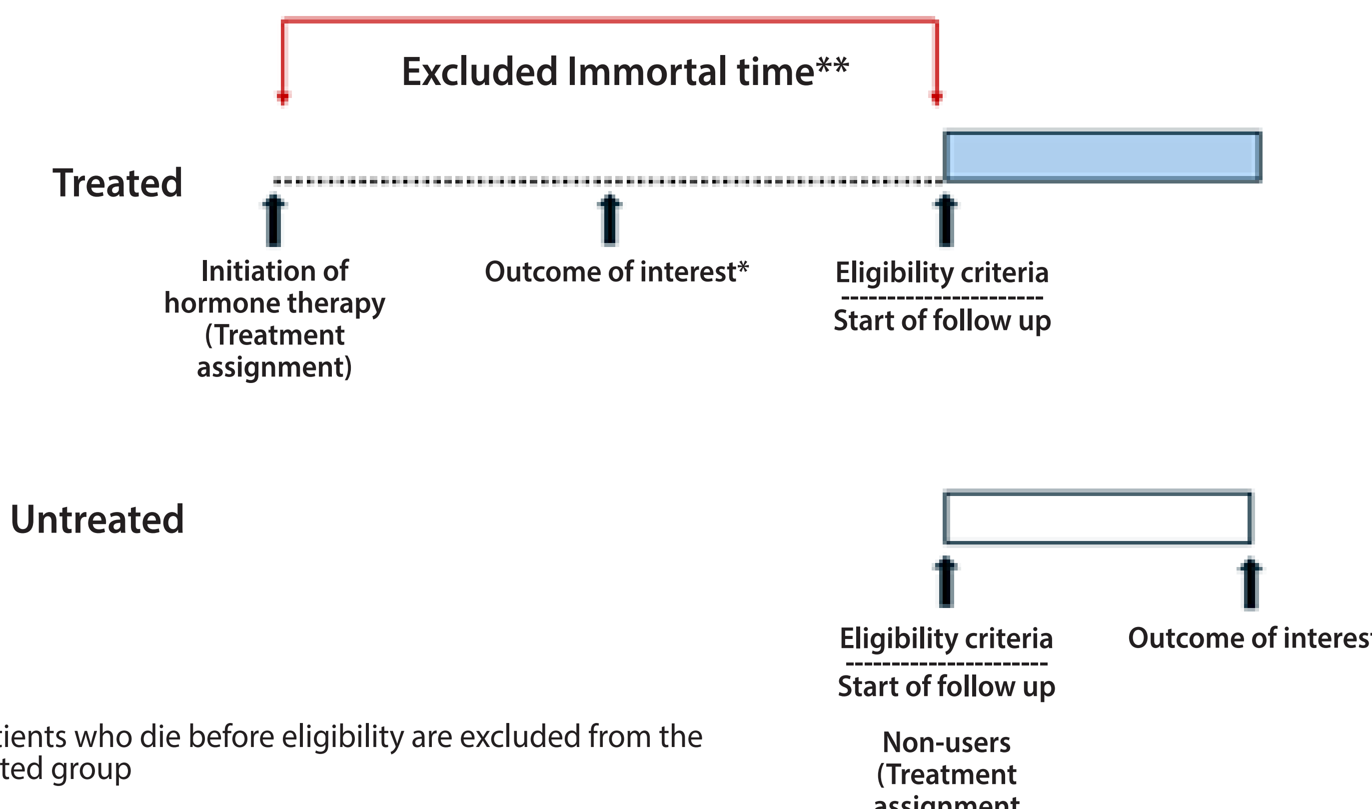
** Period incorrectly counted as part of the treatment effect, leading to biased survival estimates.

survival advantage for the treated group may be created. This bias occurs due to treatment misclassification, as the treatment strategies under study cannot be distinguished at the start of follow-up.[5] Although time zero is set at eligibility—i.e., at discharge—the treatment strategy is assigned only after time zero, such as when a prescription is filled at a later time post-discharge.

A variation of selection bias occurs when immortal time is excluded. This bias arises because eligibility criteria are applied after treatment assignment.[5] It is also known as prevalent user bias or depletion of susceptible bias, which restricts the analysis to individuals who survived a certain period after treatment assignment (Figure 2).

This type of bias was present in the 1996 observational study by Grodstein et al. examining postmenopausal hormone replacement therapy with estrogen and progestin which suggested cardiovascular (CV) benefits.[7]

On the other hand, the Women's Health Initiative (WHI)'s randomized controlled trial (RCT) found a 29% increase in the rates of coronary heart disease (CHD) among women taking estrogen and progesterone.[8] One explanation for this discrepancy is that the observational studies were biased because users and non-users of hormone therapy had different prognostic factors, resulting in healthy user bias.[9]



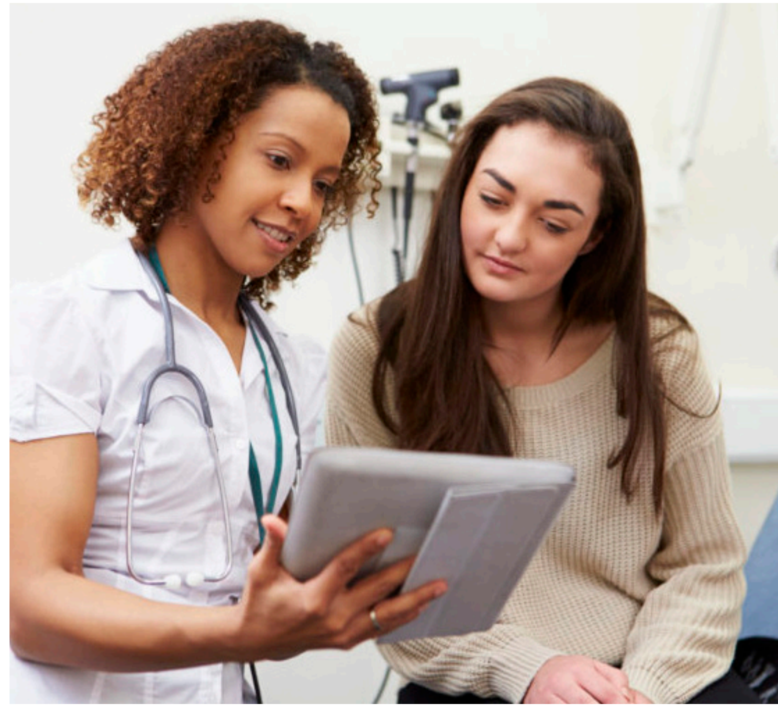
*Patients who die before eligibility are excluded from the treated group

** Excluded immortal time may lead to an overestimation of the treatment's benefit

This type of bias occurs when individuals who choose to engage in certain health interventions—like hormone therapy—are also more likely to practice other healthy behaviors (such as exercising regularly, eating well, avoiding smoking or adhering to medical advice), making it difficult to isolate the true effect of the intervention.[10]

However, it is plausible that the observational studies introduced bias by comparing current users with never-users, thereby ignoring early coronary events. As a result, high-risk individuals who experienced early events would have died, leaving behind a group of healthier survivors. This, in turn, created the appearance of better CV outcomes in the current hormone users' group in observational studies. Excluded immortal time occurs when certain time intervals are unintentionally left out, leading to bias. Consequently, enrolled patients are effectively "immortal" during these time intervals.[11]

A recent review on biases in observational studies found that 57% had immortal time bias and 44% had prevalent user bias.[12] RCTs are the gold standard for assessing the efficacy and safety of medical interventions. However, not every question can be answered by an RCT, due to practical, ethical, or resource limitations.[13] One approach to overcoming immortal time bias in observational studies is target trial emulation.



What is Target Trial Emulation?

Target trial emulation refers to designing and analyzing an observational study as if it were a specific randomized controlled trial (RCT) addressing the same question.[9] In other words, investigators explicitly imagine the "target" experiment they would ideally conduct (an ideal RCT) and then use available observational data to emulate that trial's design.

Miguel Hernán, a leading figure in causal inference, proposes two steps for conducting target trial emulation. First, investigators should articulate a causal question by specifying the protocol of the hypothetical randomized trial that would answer this question. Second, they should use observational data to emulate that trial.[13]

To articulate a causal question, investigators frame their observational study using the same six elements as an RCT: defining explicit eligibility criteria, identifying treatment strategies to compare, specifying the method of assignment, assessing outcomes, and planning the follow-up period and analysis method (i.e., intention-to-treat or per-protocol). By doing so, the observational analysis is prospectively designed in writing (even when using retrospective data) with a protocol that mirrors an RCT.

The second step is to explicitly emulate the target trial. A key component of emulation is the explicit synchronization of eligibility criteria and treatment assignment at time zero of follow-up, thereby eliminating immortal time bias. While aligning these three essential components eliminates immortal time, it does not adjust for confounders, which are external variables that influences the relationship between the independent and dependent variables.

Therefore, statistical methods such as inverse probability weighting are used to control for confounding factors.[4]

The target trial approach to observational studies has been shown to produce results that align closely with those of RCTs. As seen in Grodstein et al. earlier, there was initially a discrepancy between the findings of observational studies and RCTs. However, when Miguel Hernán and colleagues reanalyzed the observational data using the target trial approach, the results were consistent with those of the WHI study.[14]

Limitations of target trial emulation

While target trial emulation is useful for reducing certain biases, it cannot eliminate bias arising from the lack of randomization, such as confounding due to non-comparable treatment groups. Achieving an effective emulation requires comprehensive data not only on treatments and outcomes but also on potential confounders. However, routinely collected data sources, like administrative claims databases, often lack sufficient clinical details needed for proper adjustment.

Additionally, since these databases only contain information on treatments actually used in clinical practice, they cannot be applied to emulate trials for novel therapies. Moreover, emulated target trials cannot incorporate blinded treatment assignments or blinded outcome assessments, making them inherently pragmatic in nature.[9]

Summary

Immortal time bias represents a significant challenge in the interpretation of observational studies, often leading to misleading conclusions about treatment efficacy due to misclassification or selection bias. To address these biases, target trial emulation has emerged as a promising approach. By explicitly designing observational studies to mirror randomized controlled trials (RCTs), this method enhances the validity of causal inferences. As demonstrated by Miguel Hernán and colleagues, when observational data are reanalyzed using the target trial framework, the results can align closely with those of RCTs, reinforcing the credibility of this approach.

While no method can entirely replace the rigor of RCTs, careful application of target trial emulation offers a valuable strategy for enhancing the reliability of observational studies. Recognizing and addressing biases like immortal time bias is essential for advancing evidence-based medicine and ensuring that treatment decisions are grounded in accurate interpretations of data.

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AI Skills: The New Currency in Today's Job Market

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TV pundits and talking heads love to get riled up about whether robots are coming for our jobs — but the truth is that AI will probably create more jobs than it eliminates. And one thing's for sure: understanding how AI works, and mastering AI skills, will be the key to success in tomorrow's ever-changing world of work.

New research shows that a growing number of companies are asking for AI skills in job descriptions — including non-tech roles. And a survey of HR professionals released last month shows that job candidates with AI skills ask for more money during the interview process — and tend to get it once they're hired. Simply put, AI is going to be underpinning nearly every job out there. That's why staying ahead of the latest in AI development is so important.

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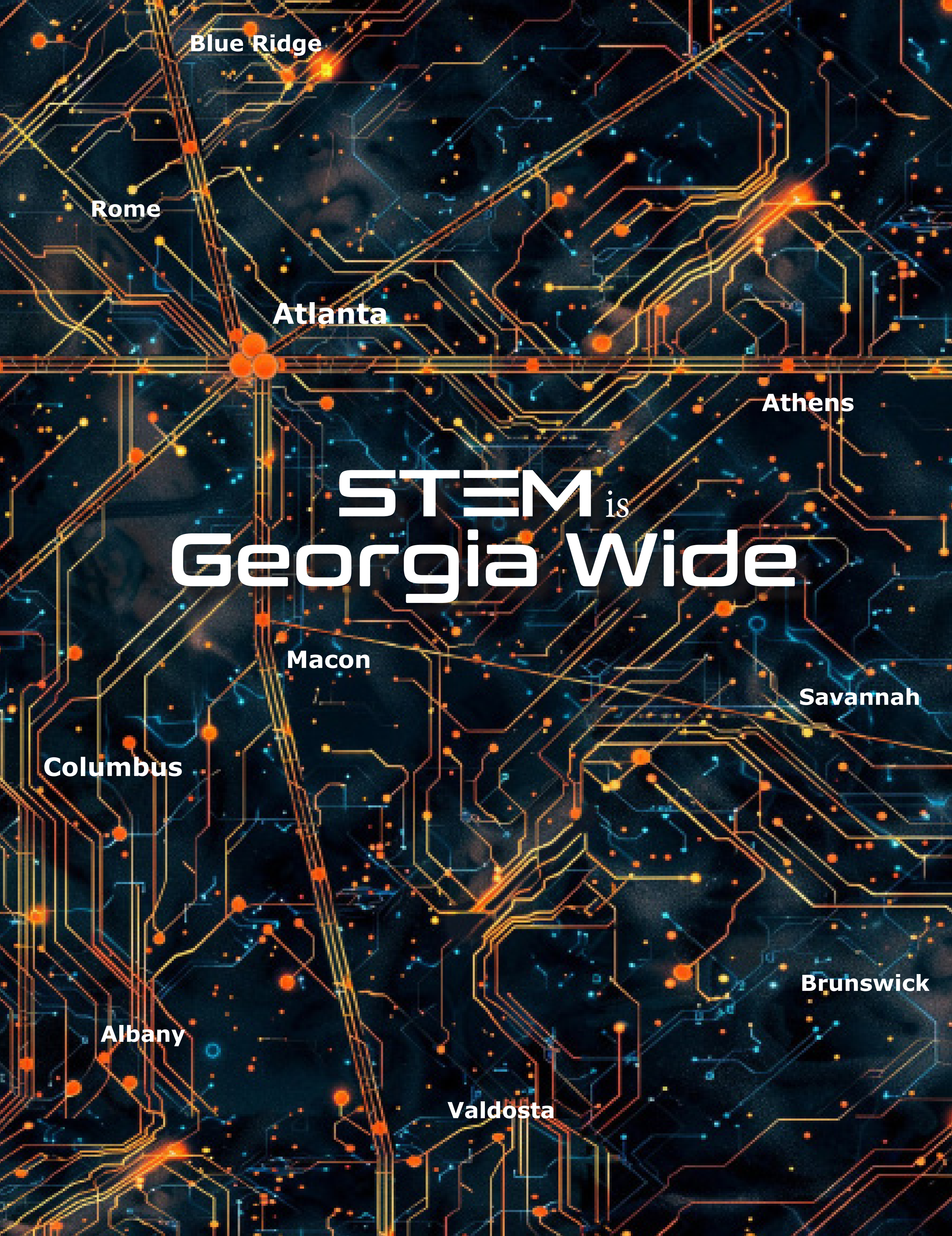
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