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The International Journal of

SOCIAL GOOD AND INNOVATION FOR YOUTH

Climate Action

*Clean energy,
sustainable materials,
using biomimicry to
innovate*

Purposeful Learning and Maker Spaces to Engage Students

*Building student
confidence and creativity*



EMPOWERING STUDENT VOICES IN STEAM

***Bias and Student Work in the
Age of Generative AI***

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“STEM opportunities, as provided through this journal, challenge the status quo by opening doors and breaking down walls. It is a call to action: to democratize science and ensure that every student, regardless of background, has the chance to participate.

This journal is designed to be a launchpad for student research, a place where young scientists can publish their findings, share their insights, and connect with a broader community. By providing access to publication and mentorship, the journal helps students navigate the often-intimidating world of academic science. It recognizes that brilliance isn't confined to elite institutions or expensive labs - it can be found in classrooms, garages, and even kitchen tables. All it needs is a platform.”

Imran Allarakhia, Senior Editor, International Journal of Social Good and Innovation for Youth.



Engaging Teens Through Stem: Inclusion, Getting Beyond Apathy and Designing the Curriculum for Purposeful Learning

Equity In Stem: Creating Inclusive Platforms for Youth

By Imran Allarakhia, Senior Editor IJSGI

Canada Wide Science Fair Gold Winner, Top in Digital Technology



Equity in STEM

In a world that is constantly evolving and changing, the principles of science, technology, engineering, and mathematics - better known as STEM - are not and should not be niche fields reserved for a select few. They are and will continue to be the driving forces behind the innovations shaping our collective future. From solutions for the current climate crisis to developing medical breakthroughs, integrating advanced artificial intelligence systems into society, and potentially venturing the stars through space exploration, STEM disciplines have taken center stage in nearly every aspect of modern life. As the pace of change accelerates, so too does the inherent need for fresh perspectives, bold ideas, and this can only be accomplished through inclusive platforms that are designed to empower the next generation of thinkers and problem-solvers.

STEM opportunities exist to meet that need. At its core, STEM has and will always be focused on passion. It's about giving students who love STEM a space and opportunity to express their curiosity, creativity, and unique viewpoints. Science is not a rigid set of facts and ideas; it is a process of exploration, questioning, and discovery. STEM opportunities aims to celebrate that process of discovery by encouraging students to showcase their own research and understanding of the world around them, by utilizing the science discovered by those before them. Whether through research, experimentation, or theoretical inquiry, the goal is to amplify voices that might otherwise go unheard.

One of the most powerful truths about science that is unfortunately not stated nearly enough is, that it belongs to everyone. Curiosity is a universal human trait. It is what drives us to ask “why,” pushes us to seek answers, and to imagine new possibilities never thought before. Yet, too often, access to scientific platforms and opportunities is limited by numerous barriers such as funding, gatekeeping, or lack of exposure. These obstacles prevent brilliant minds from sharing their ideas and contributing to global conversations. STEM opportunities, as provided through this journal, challenge that status quo by opening doors and breaking down walls. It is a call to action: to democratize science and ensure that every student, regardless of background, has the chance to participate.

This journal is a manifestation of that mission. It is designed to be a launchpad for student research, a place where young scientists can publish their findings, share their insights, and connect with a broader community. By providing access to publication and mentorship, the journal helps students navigate the often-intimidating world of academic science. It recognizes that brilliance isn't confined to elite institutions or expensive labs - it can be found in classrooms, garages, and even kitchen tables. All it needs is a platform. Ultimately, the value of STEM opportunities lies in its belief in the transformative power of student voices. When we empower young people to explore, question, and innovate, we are not just investing in their futures – we are investing in the future of humanity. Because at the heart of every scientific breakthrough is a spark of curiosity. And when that spark is nurtured, it can light the way to a better world.

Purposeful Learning: Preparing for the Future with Intention

By the BioEndeavor Staff



Why Purpose Matters

Purposeful learning goes beyond memorizing facts or passing exams. It is about engaging with big questions: What do I care about? How can I use my skills to make a difference? Where can my passions take me? When teens approach education with these questions in mind, STEM become more than part of a course, it becomes a launchpad for solving problems in local communities, for entrepreneurship, and contributing to the Sustainable Development Goals. In this respect, through purposeful learning, students can see themselves as contributors to the world around them.

Beyond the Classroom: Building Experiences That Count

Employers, universities, and communities are increasingly looking for more than academic excellence. They value people who can demonstrate initiative, creativity, and leadership through real-world experiences. This includes being competent across a variety of soft skills such as collaboration, communication and networking skills, systems thinking and being able to see the larger picture, critical thinking and innovative problem solving, empathetic and moral leadership. Given these expectations, we need to create purposeful, educational experiences that take students beyond the classroom - engaging SMEs and NGOs in solving community problems, working with local leaders as part of civic engagement, through science fairs and other competitions to expose students to diversity of thought and critical thinking experiences, encouraging learning opportunities that connect the STEM disciplines with the skilled trade disciplines, entrepreneurship skillset development in partnership with universities and colleges.

The BioEndeavor STEAM for GOOD Accelerator

One example of the purposeful learning approach is the BioEndeavor STEAM for GOOD Virtual Accelerator. Designed for middle and high school students, the program provides opportunities to explore science, technology, engineering, arts, and math (STEAM) through the lens of social good. Through mentorship from university faculty, graduate students, and professionals, participants discover what purposeful learning looks like in action at a local and global level. Students build connections with NGOs, startups, and thought leaders, gaining early exposure to the types of collaborations they will experience in post-secondary studies, in internships, and apprenticeships.

Preparing for the Future with Intention

The accelerator's focus is not simply on preparing teens for university or college admissions, it is about preparing them for life. By weaving together purposeful learning and hands-on experiences, students learn how: to design passion projects that make a difference and build confidence through real-world problem solving. They can visualize the connections between classroom subjects and career pathways, and craft a portfolio that reflects not just what they know, but who they are and want to be. These are the life skills we must support through in classroom and extracurricular STEM opportunities. This journal provides one such opportunity for teens to share their thoughts and achievements in STEM.

Getting Beyond Teen Apathy

By Diego Gomez

Avid Film Maker

In recent years, there has been a growing concern about the rise of apathy among teenagers. Apathy, defined as a lack of interest, enthusiasm, or concern, appears to be a defining trait among many adolescents today. This indifference extends to politics, environmental issues, academics, and even personal relationships. It can be tempting to label this trend as mere laziness or immaturity. However, a deeper exploration reveals a complex web of psychological, societal, and technological influences that contribute to this “disengagement”.

One major influence is the pervasive role of technology and social media. Constant digital stimulation can leave teens emotionally numb, while the curated nature of online life can lead to feelings of inadequacy or detachment from reality. Academic and societal pressures also play a role. The modern education system often emphasizes grades and test scores over creativity and personal development. Many teens report feeling like they're on a treadmill, working hard without a clear sense of purpose. Teen apathy can manifest in different ways. A once engaged student may stop caring about school. A teen who used to enjoy sports or clubs could suddenly withdraw. They may show little interest in planning for the future or avoid responsibility as well. When teens stop caring about their future, their relationships, or themselves, this can result in poor academic performance and social isolation.

Teen apathy is not a personal deficiency; it may very well be a reaction to overwhelming and complex contexts. When we consider what creates this disconnection, we can provide empathy based and purposeful support to help them rediscover a sense of meaning, passion, and hope. Rather than paint teens as apathetic, we must understand their silence as a plea for understanding, and respond with compassion, creativity, and commitment.



Quality Education is a Right for All

By Kaitonna Ezomike

Published Author, IB Student



Sustainable Development Goal 4 focuses on “Quality Education for all”. While it may seem achievable, given the current impact of education, I am deeply worried about the next generation of students. We have a long way to go before everyone has access to quality education, much less than the 6 years the United Nations (U.N.) is giving us. This includes both

developing and developed countries. Governments are not spending what they should be in both developing and developed countries on education - from primary, secondary to post-secondary education. (Only 50 percent of students believe that what they’re learning is relevant to the real world)

A Matter of the Curriculum: My Personal Experience

The STEM curriculum being taught and the pace at which it is being taught varies quite a bit across countries, states, and even schools. I share here my own experience with math. At first, I pursued math normally, the same as any other student my age. However, when I was eight, my mom introduced me to a great series called Life of Fred.

I started by completing some simple addition math but in just 4 years of studying the series, I was doing calculus. When I was working on pre-algebra, the book indicated that the material was for grades 6-8, and I thought for sure that I would see this material in middle school. When I attended middle school, we were working on integers and fractions. What happened? Was it that I had simply accelerated, was it the disruptions caused by COVID-19? My worry is about the preparation needed to succeed in high school and then university or college. Math is a subject that requires steady exposure and practice with the concepts, in order to succeed in the years that follow.

Where I live, education is a responsibility of the government. Reduced investment in education by the government is impacting students, the teachers (who are overwhelmed), and will ultimately impact the competitiveness of our country if students do not feel comfortable with STEM. In this way, citizens could end up becoming more reliant on the social safety nets provided by the government. This is not the first time in history that governments are structuring the curriculum to instruct students on what to think, rather than how to think. Many different countries are grappling with this problem. Not thinking for themselves (also known as critical thinking) can impact our students’ ability to solve problems and find solutions to the great challenges of our world.

My Concern for the Next Generation of Students

The farther I made it through ‘Life of Fred’, the more concerned I became about the math curriculum. Last year, I was showing a trick to my friends using advanced algebra to prove that 2^2 wasn’t actually 4 (visit [BioEndeavor](#) to download the math problem for your students), but when I showed my proof, students were not open to the math concepts. In fact, I was mocked for my solutions.

I can see that students are seriously struggling with simple math concepts. These are foundational concepts that will impact students’ ability to master future math concepts. Students are not keeping pace with the math curriculum. Furthermore, I hear many times that students simply do not understand the real-world application of these concepts.

Change is needed. The only way to bring about change, without stressing and confusing students is to make the changes slowly. This may not be possible in the 6 years the U.N. hopes to achieve the 2030 Agenda. While we are focused on education in developing countries, it is important to also look at the education system in developed countries. If change doesn't happen soon, students will enter the world not knowing the mathematical skills they need to survive.

What can we do about this as students?

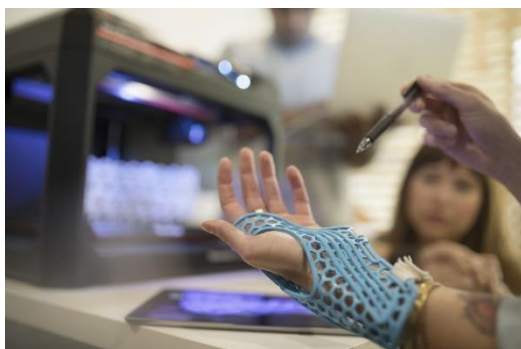
We have to act fast or several generations will be impacted. We need to create circles of change ourselves. What can you do? Find opportunities any time you can challenge yourself in STEM. Challenge yourself at home or anywhere and carry on your learning after school. Ask for more challenging books on a subject you like. Find someone to help you do better on other subjects you don’t enjoy as much.

Then, try to help other people around you. This problem can’t be solved by just one person. Share the problem with as many people as possible. My parents are always telling me to go above and beyond, but now I realize it’s not just because I can, it’s because I need to, otherwise I will not achieve my full potential in life. We need to become better at spreading awareness about the importance of STEM to bring about local change. If something doesn't change soon, an entire generation of students might find it almost impossible to make it through a very competitive, technologically driven world. We can do this together through our own circles of change. If we can do these things, we can get ourselves, and as many people as possible, ready for the world outside of our homes and communities.

Supporting Youth-led Innovations for the SDGs through school-sponsored Maker Spaces

By Saylor Baker

Avid Maker, Social Innovator



Education is an important tool to build healthier, stronger, and more peaceful communities. In fact, it is so important that the United Nations has included it in its list of 17 global goals to support climate action, economic growth, and social development. Known as the Sustainable Development Goals (SDGs), these global ambitions are a chance for all people of the world, including youth, to come together and work to create solutions to our biggest and hardest

problems - things like ending poverty, food insecurity, and equality.

Education is listed specifically as Goal 4, that is Quality Education, but it is also an important factor for all of the goals. Education can spread awareness of healthy practices, support Goal 3 or Good Health and Well-being; it can empower girls and change negative stereotypes, supporting Goal 5: Gender Equality; it can create the innovation needed to achieve climate action (Goal 13) and sustainable cities and communities (Goal 11). But what kind of education is needed? Does the classroom I sit in every day really help us to work towards these massive goals? I propose a wider view on schools and learning and put forward “makerspaces” as a positive tool to support place-based education and design thinking with our communities. In this respect, makerspaces align with purpose-based education with a focus on meeting the U.N. Sustainable Development Goals at a local level.

Maker Spaces

What are “makerspaces” and their value for education? As defined by Merriam Webster, makerspaces are “a communal public workshop in which makers can work on small personal projects.” The Cambridge dictionary defines them as “a place where people can come together to create or invent things, either using traditional crafts or technology.” I think of makerspaces as learning laboratories, where people can tinker, invent, dream up new ideas, and be inspired by others. The incredible maker spaces that I have seen offer access to equipment like 3D printers, computer software, laser cutters, and even woodworking tools such as table saws and drill presses. These spaces provide people with the tools they need to build and create things with a variety of scales and materials, often solving problems or inventing things that make life a little easier.

Makerspaces have a place at all levels of education. They can be made available in elementary schools including through partnerships with local libraries and community spaces. In high school, traditional learning spaces like woodshops and engineering labs have become makerspaces (they have always existed as direct learning spaces but are now transforming to adopt the maker spirit of creativity and experimentation through things like competitions and open lab time). And universities are known for incorporating these spaces into the core curriculum, and as part of extracurricular activities and entrepreneurship.

Why Maker Spaces Matter in Education

Maker spaces are important because they allow ideas to be put into action. Some of our greatest inventions have been a result of imagination, tinkering, and building. Thomas Edison perfected the lightbulb after testing thousands of different materials. Orville and Wilbur Wright were bicycle mechanics who spent years experimenting with gliders and engines before they flew the world's first airplane, and personal computers were invented in the garage of Apple founder, Steve Wozniak. When people are given the time, tools, and space needed to create things, big life-changing inventions can happen.

Including maker spaces as a part of education is important because it allows students to learn by doing. Reading textbooks and following PowerPoints are helpful, but building things with our hands is memorable, and helps students put into action what is being taught. Maker spaces have an especially important place in STEM education because students can see what concepts look like in action while being able to prototype their own ideas using what they learn. In a makerspace, young people learn by experimenting, designing, building, failing, and trying again. This type of education can build creativity and problem-solving skills for students, while encouraging us to feel confident in our skills and empowered to take on big challenges.

Solving Global Problems

Allowing young people access to maker spaces is especially important because we bring a new perspective to solving problems. Young people can come up with ideas that older scientists might miss. Besides, the SDGs have been called an “intergenerational” effort because things like climate change cannot be solved in only a few years. It will take both current scientists and future scientists to find solutions to ending issues like global warming and create a healthier and better planet. The bottom line is that young people and students can carry on current scientific progress and offer important new solutions, but we need the space to dream and put wild ideas into practice.

Besides fresh eyes, young people also have a history of inventing big things. Albert Einstein presented his theory of relativity at age 26. Alexander Graham Bell patented the telephone at age 29, and Joseph-Armand Bombardier built the world's first snowmobile at the age of 15! Young people should not be left out of efforts to find solutions or build things that might help humanity. History has proven that our ideas have value. The Time Magazine Kid of the Year for example, features countless young inventors and makers using their ideas and resources to make the world a better place, one step at a time. We should be able to make these opportunities available to all students and encourage everyone to give their ideas a chance. Who knows where they could lead.

By using maker spaces in education, students will be given an opportunity to learn more deeply and practically about the concepts in their textbooks. They will also be given the space and opportunity to create great things, things that can solve problems or make life better, things wild enough that only a young mind might think it up. Maker spaces have an important place in schools at all levels, including high school and college. By incorporating maker spaces into education, we can advance two key topics that should not be overlooked: the power of youth and the necessity of innovation.



Thinking Bigger When Talking About Climate Change, Empowering Green Innovation

“Climate change is arguably one of the defining issues of our time, negatively impacting marginalized communities that generally do not have the relative resources that other communities have in contending with climate change and adapting and recovering from these disruptions.”

Bhairav Tanish Machireddy and Obra D. Tompkins

How Climate Change is Reshaping Adolescent Mental Health in Underserved Communities, and the Role of Youth-Driven Solutions in Building Emotional Resilience and Climate Awareness

By **Bhairav Tanish Machireddy** (BioEndeavor Student Researcher) and **Obra D. Tompkins**



Abstract

Climate change is arguably one of the defining issues of our time, negatively impacting marginalized communities that generally do not have the relative resources that other communities have in contending with climate change and adapting and recovering from these disruptions. Youth living in these disadvantaged positions experience not only ecological disruptions, but they are also facing increasing levels of psychological distress. This paper explains how climate change exacerbates adolescent mental health in under-resourced populations, the significance of youth-led responses in promoting emotional resilience and raising climate awareness amongst their peers.

Climate Change and Mental Health Impacts on Adolescents in Underserved Communities

For many young people in disadvantaged communities, climate change is not something that is going to happen in a few years - climate change is already affecting their day-to-day lives. Young people living in disadvantaged communities experience an increase in climate-related disasters such as flooding and heatwaves, increasing food insecurity, and an increase in anxiety, depression, and symptoms of traumatic events. Research suggests that climate instability related stressors have an additive effect on existing vulnerabilities related to socioeconomic disadvantages such as poverty and lack of access to mental health care (Clayton et al.; 2017; UNICEF). Young people in disadvantaged communities are particularly affected because the chronic uncertainty about how their environment is going to change deepens feelings of helplessness and hopelessness, can negatively impact their cognitive abilities and academic performance at a time when they are developing and growing (Miles and Sullivan, 2022).

Youth-Driven Solutions as Pathways to Resilience

Despite these challenges, youth are stepping up and leading solutions that develop community resilience and personal resilience strategies. Youth-led solutions that create safe spaces for young people to express their fears and then transform that fear into something positive, such as peer support, school climate clubs, or community advocacy projects, provide protective advantages (Hickman et al., 2021). In these groups, young people further develop executive function skills that deal with problem solving, self-regulating, and collaborative social skills when they experience outcome efficacy in dealing with stress. An example of this is a systematic review of youth-led climate resilience and adaptation in under-resourced communities that found that participation in youth-led climate resilience activities has positive correlates of improved emotional health and experience of agency for the adolescent population (Mackenzie and Roy, 2023).

Not only do the groups improve mental health, but the groups are also pedagogically mindful and improve climate literacy and empower young people to have the knowledge and tools to have climate literacy outcomes in their community.

Challenges to Implementation and Equity

Despite the potential of youth-driven solutions, systemic barriers remain. Typically underserved communities tend to have underfunded schools, and the lack of available mental health resources. To promote equitable access to youth programming, collaboration amongst policymakers, educators, and community organizations is required. In addition, youth engagement will only be productive and effective with youth programming that takes into consideration cultural relevancy and the lived experiences of youth from diverse backgrounds (Clayton et al., 2017).

Conclusion

Climate change presents significant mental health challenges for youth in under-resourced communities, exacerbating social disparities. Recognizing that youth-led approaches can serve as powerful agents of emotional resilience and climate literacy should instigate action. Facilitating youth-led initiatives through inclusive governance and resource allocation can empower youth as agents of change while preserving their emotional health. Future research can leverage the lessons learned by assessing longitudinal impacts of youth engagement and identifying the best practices for scaling programs among a wide variety of communities.

References

- Clayton, S., Manning, C. M., Krygsman, K., & Speiser, M. (2017). Mental health and our changing climate: Impacts, implications, and guidance. American Psychological Association and ecoAmerica.
- Hickman, C., Marks, E., Pihkala, P., Clayton, S., Lewandowski, R. E., Mayall, E. E., Wray, B., Mellor, C., & van Susteren, L. (2021). Climate anxiety in children and young people and their beliefs about government responses to climate change: A global survey. *The Lancet Planetary Health*, 5(12), e863–e873. [https://doi.org/10.1016/S2542-5196\(21\)00278-3](https://doi.org/10.1016/S2542-5196(21)00278-3)
- Mackenzie, S. H., & Roy, C. L. (2023). Effectiveness of youth-led climate resilience programs in underserved communities: A systematic review. *Environmental Research Letters*, 18(4), 045001. <https://doi.org/10.1088/1748-9326/acb8f5>
- Miles, J. C., & Sullivan, C. A. (2022). Environmental stress and executive functioning in adolescents: The moderating role of social support and community engagement. *Journal of Youth and Adolescence*, 51(5), 915–930. <https://doi.org/10.1007/s10964-021-01506-y>
- United Nations Children’s Fund (UNICEF). (2021). The climate crisis is a child rights crisis: Introducing the Children’s Climate Risk Index. UNICEF. <https://www.unicef.org/reports/climate-crisis-child-rights-crisis>

An Ancient solution to a Modern Food Science Problem: Neem and Turmeric essential oil-based solutions for STEC/EHEC elimination on produce

By **Rakshan Saravanan** (Canada Science Fair Participant, BASEF Gold Winner), **Amanda Vanderveen**, **Dr. Keith Warriner**



Abstract

Shiga Toxin-Producing *Escherichia coli* (STEC/EHEC) contaminates raw produce, causing severe illness such as Hemolytic Uremic Syndrome. Current sanitation methods are ineffective. This study developed a natural, food-safe antimicrobial using *Azadirachta indica* (Neem) seed oil and

Curcuma longa (Turmeric) essential oil. Disk diffusion assays determined optimal concentrations, with the best formulation being 10% Neem oil and undiluted Turmeric oil. When tested on inoculated lettuce, the mixture achieved a 91.14% (log 1.05) bacterial reduction. These results demonstrate a potent, sustainable solution for reducing STEC/EHEC contamination, supporting traditional medicinal findings and offering a viable household food safety approach.

Background

Annually, contaminated food causes 600 million disease cases and 420,000 deaths worldwide - 30% of these deaths occur in children under 5 years of age (World Health Organization, 2019). The gram-negative bacteria *Escherichia coli* (*E. coli*) includes Shiga toxin-producing *E. coli* / Enterohemorrhagic *E. coli* (STEC/EHEC) (Mueller & Tainter, 2023), which is the most globally significant pathogen. Approximately 1.2 million new cases are reported globally every year (Travert et al., 2021).

A significant portion of STEC/EHEC infections result from the consumption of contaminated produce such as salad lettuces. Research has shown that STEC/EHEC can be introduced via multiple sources such as bovine fecal matter as well as the fecal matter of other ruminants such as goats through runoff, and its persistent nature makes it difficult to eliminate (Meshari Ahmed Alhadlaq et al., 2024).

Current sanitizing methods have limited effect on eliminating STEC/EHEC. Industrially, a three-step wash cycle is commonly done using chlorine-based sanitizers which tend to spread bacteria rather than eliminate them (CBC/Radio-Canada, 2018).

Domestic guidelines recommend washing produce with cool water and drying with disposable paper towels to eliminate bacteria (Food and Drug Administration, 2020; FoodSafety.gov, 2021). Unfortunately, bacterial biofilms created by STEC/EHEC are strongly adhering, and rinsing with water is not effective at inactivating or removing them (Hirsch, 2019; Brás et al., 2024). Acetic acid solutions can be used; however, using acetic acid is ineffective against acid-resistant serotypes of STEC/EHEC strains (Price et al., 2004). To ensure elimination of bacteria, cooking produce at 70°C is recommended (World Health Organization, 2018); yet this is not suitable for produce commonly eaten raw, like salad.

Given the global prevalence of infections from consuming contaminated produce, there is a clear need for effective sanitization of select produce prior to consumption.

Proposed Methods

Given the current limitations in sanitary guidelines for produce, it is important to outline the key aspects of a proposed alternative:

- The sanitation solution may be fully bactericidal against STEC/EHEC without hindering the edibility of produce.
- The sanitary process is Generally Recognized As Safe (GRAS) and does not pose risk to consumers through residual contaminants.
- The sanitation process must be completed in relatively little time (5–10 minutes).
- The sanitation process must not hinder the flavour of produce.
- The sanitation process must be economically and environmentally sustainable.

The sanitation process must adhere to multiple requirements. Accomplishing them may require the review of traditional medicine. *Azadirachta indica* (Neem) is a deciduous, fast-growing tree of the Meliaceae (Mahogany) family that can survive in a variety of environments (Petruzzello, 2019; Winrock International, n.d.).

The traditional medicine of Ayurveda has used Neem bark, leaves, seeds, fruits, roots, and oil to treat various ailments (Herrera-Calderon et al., 2019). Some uses include treatment for malaria, septic sores, and infected burns, suggesting early practice of Neem as an antibacterial medication (National Research Council [US] Panel on Neem, 1992).

Recent data support the antibacterial qualities of Neem. In ethanolic, methanolic, and aqueous extracts derived from the leaves and seeds of Neem, various studies suggest a bactericidal/bacteriostatic effect against gram-positive and gram-negative bacteria at varying concentrations in vitro (Ali et al., 2021; Altayb et al., 2022; Alzohairy, 2016; Mahmoud et al., 2024; Jimenez Rios et al., 2024; Wylie & Merrell, 2022; Wylie et al., 2022). Neem has shown to inhibit biofilm formation of select *Methicillin-resistant Staphylococcus aureus* (MRSA) strains in both ethanol and petroleum ether (Prabu et al., 2020) as well as eliminate bacterial biofilms (Meshari Ahmed Alhadlaq et al., 2024; Wylie & Merrell, 2022). Such studies also suggested that an increase in extract concentration resulted in greater antibacterial effects.

The bactericidal nature of Neem derives from its terpenoids. Terpenoids are derivatives of terpenes, a collection of isoprene (C₅H₈) units with oxidized methyl groups and possibly additional oxygen atoms. Literature has described terpenoids as antibacterial due to their lipophilicity and hydrophobic nature along with the presence of hydroxyl (OH) groups in their structure (Cordero et al., 2018).

Multiple methods of action of these compounds on gram negative bacteria such as STEC/EHEC are theorized.

The literature thus far has reviewed extracts but not the seed oil (EO) of Neem, despite it having the highest concentration of terpenoids compared to other plant parts. Given that up to 60% of Neem seed mass is oil, it is a key component for investigation in creating a solution (Hamadou et al., 2020).

However, to test concentration on inhibition, a miscible solvent is needed to act a medium of dilution, while at GRAS to consume for practical application. For this, 70% food grade ethanol is to be used (Syahadat and Diningsih, 2022). Lastly, in consideration that the primary substance may be Neem seed oil, being an oleic substance, the solution must be kept in cool, dark conditions to be preserved. In practicality, the solution may need to be used in locations without such qualities given that STEC/EHEC is a global concern. Therefore, the use of *Curcuma longa* (turmeric) rhizome Essential Oil (EO) would be optimal (Prasad and Aggarwal, 2011).

The majority of an EO's mass derives from terpenoids and terpenes at high concentration (Zhao et al., 2024). Turmeric rhizome has shown antioxidative and antibacterial activity due to its terpenoids - such as curcumin and turmerone - which may enhance the solution's effectiveness.

Overconsumption of Neem seed oil may cause diarrhea, so dilution is necessary. Although this may decrease bactericidal activity, it can still achieve the required 3-log reduction of STEC/EHEC CFU.

Methods

Materials used

- K-12 E. Coli Saline solution
- Neem Seed oil
- Turmeric Rhizome Essential Oil
- 70% food-grade ethanol
- Dilution tubes
- Vortex
- Incubator
- Micro pipette
- Stomacher bag
- MacConkey Agar plates

A three-step testing process was conducted to make a solution. Testing against a prepared saline-solution of non-pathogenic K-12 E. Coli (10^8 /ml). A disk diffusion assay was conducted with neem seed oil and turmeric EO (100%, 10%, 1% and 0.1%) solutions in 70% ethanol. The prepared agar plates were incubated at 37 C° for 48 hours. Individual inhibitory action on the K-12 was recorded, a disk with a clear zone of 11mm was classified as the Minimum Inhibitory Concentration (MIC).

Synergistic testing was conducted to see if turmeric rhizome EO enhanced neem seed oil inhibitory effects. Another disk diffusion assay was performed under similar conditions, with antibiotic solution of one dilution below the MIC of Neem and 100% turmeric rhizome EO.

This synergistic solution was used in practical testing stage. Various trials were conducted including control. Lettuces were inoculated with the K-12 solution to adhere for 30 minutes. In solution trials, equal volume of solution was applied to adhere for 10 minutes. Lettuces were placed in Stomacher bags creating 10% saline solution of the residual K-12. These bacterial dilutions were further diluted (10%, 1%, 0.1% and 0.01%). One mL of each was placed on MacConkey Agar plates (*E. coli* specific) and left to incubate at 37°C for 48 hours. Colony forming units (CFU) were then counted and CFU/ml was calculated. This process was repeated for differing concentrations of neem seed oil (1%, 10%). Percent and log reduction was calculated.

Results

Individual inhibitory effect:

After incubating the plates, the Zones of Inhibition (ZOI) were observed. Given that a treatment against K-12 *E. Coli* must show a ZOI of at least 11 mm to be considered the Minimum Inhibitory Concentration (MIC) to be an antibiotic, 1% Neem Seed Oil matched this criterion with ZOI of 14 mm, and possibly antibacterial with STEC/EHEC. Turmeric rhizome EO showed minimal inhibition in all concentrations as ZOIs did not surpass 8 mm. This suggests that the turmeric rhizome EO is not effective at eliminating K-12 *E. Coli*. With this, neem seed oil seemed to be primarily antibacterial. However, turmeric rhizome has been traditionally mixed with neem in ayurvedic medication, thus potential synergism was tested.

Synergistic effects:

Synergism was found between the 0.1% neem seed oil and 100% turmeric rhizome EO. The ZOIs averaged 16 mm, showing an average 14.29% increase in ZOI of the MIC of neem and this was 79.78% greater than the 8.9 mm ZOI found in 0.1% neem seed oil. Given that the only variable changed was the addition of 100% turmeric rhizome EO, suggests great synergism between the two components. The resulting solution was more potent against STEC/EHEC as its ZOI is now significantly above 11 mm at a lower concentration of neem seed oil.

Practical testing:

Given that the synergistic solution used exhibited superior effects, it was initially used in this testing. CFU was manually counted on the 0.01% plates as higher concentrations results were too numerous to accurately count. The actual CFU was calculated, using a dilution factor of 10000 and 0.1 ml to find true CFU. The average residual CFU for control trials was 3.10×10^7 and for treatment trials was 1.665×10^7 . With this, the log reduction and percent reduction were calculated. Thus, the solution of 0.1% neem seed oil and 100% turmeric rhizome EO showed an average of 46.29% reduction in CFU (log 0.27 reduction).

This solution was able to exhibit significant inhibition at the smallest concentration of neem seed oil, of which data from individual inhibitory testing showed to be the primary antibacterial element. The data also suggested the inhibitory effects of neem seed oil increased with concentration; thus, additional trials were conducted under similar conditions with treatments with higher concentrations of neem seed oil (1%, 10%) while turmeric rhizome EO was kept the same.

Treatment trials showed an average of 1.435×10^5 CFU/mL (1% neem seed oil) and 3.10×10^4 CFU/mL (10% neem seed oil) residual K-12, consecutively showing a 59% and 91.14% reduction (log 0.38 and log 1.05 reduction).

Discussion

Global food contamination by Shiga toxin–producing *E. coli* (STEC/EHEC) can cause serious illnesses including Hemolytic Uremic Syndrome and Hemorrhagic Colitis, both potentially lethal in young children (Travert et al., 2021). Current food sanitation methods are flawed as they do not effectively eliminate STEC/EHEC on leafy produce.

This solution's antibacterial function is attributed to its terpenoids. Literature proposes multiple mechanisms of action such as rupturing the cell membrane and altering ion channels, leading to leakage of intracellular constituents and inhibition of target enzymes, which can prevent antibiotic resistance (Guimarães et al., 2019).

Gram-negative bacteria have porin channels mediating antibiotic entry. Another theory suggests that it may be that through these porin channels, the terpenoids, given that their molecular mass is relatively low and with the presence of hydroxyl groups, enter the bacteria and cause cell rupture. The lipophilicity of terpenoids in this instance aids greatly especially when accompanied by low molecular mass, aiding facilitation into the cell structure. This is a challenge with current antibiotics. It is also theorized that the hydroxyl groups of the compounds are highly reactive with the cell, forming hydrogen bonds with the active locations of target enzymes - thus, inactivating them and causing dysfunction or rupture to the cell wall (Guimarães et al., 2019).

Select terpenoids in Neem leaves such as β -D-Mannofuranoside and O-Geranyl may dock upon bacterial binding proteins similarly to antibiotics, stimulating autolytic enzymes that degrade peptidoglycan layers (Altayb et al., 2022; Prabu et al., 2020). Other studies show that terpenoids can disrupt bacterial biofilms by altering the fatty acid composition of the cell wall membrane, increasing hydrophobicity, and causing disintegration (Leite et al., 2022).

Significance

This research focused on producing a novel and viable solution for produce decontamination. The Neem–turmeric solution eradicated *E. coli* on produce using low quantities of Neem seed oil, the primary antibacterial element. It can be applied in both domestic and industrial environments to reduce global STEC/EHEC infections. The solution is both edible and sustainable. Neem seed oil can be produced via cold pressing, an eco-friendly method with a low carbon footprint. Large quantities can be produced sustainably as only small concentrations are required (Hamadou et al., 2020). Neem seed and turmeric rhizome pulp, when mixed into manure, prevent root rot and supplement nutrients in soil (Ozone Biotech, 2025).

Conclusion

After multiple trials, it was found that a solution of 10% neem seed oil mixture with turmeric EO resulted in a 91.05% reduction in bacterial colony units. This solution is easily applied to produce and provides the potential means to remove K-12 *E. Coli*, with minimal environmental impact.

Future Trials

Since it was found that neem seed oil was the primary antibacterial element and turmeric rhizome EO enhanced its functionality, future trials should be performed with increasingly higher concentrations of neem seed oil (15%, 20%) while keeping the turmeric rhizome EO concentration at 100%, to find the concentration of neem oil that results in a log 3 reduction. Knowing the correct ratio of the oils, a mechanism of delivery could be developed for application in domestic and industrial settings.

References

- Ali, E., Alhaji, N., Mohamed, A., & Hassan, H. (2021). Extract of *Neem (Azadirachta indica)* leaf exhibits bactericidal effect against multidrug resistant pathogenic bacteria of poultry. *Veterinary Medicine and Science*, 7(5), 1921–1927. <https://doi.org/10.1002/vms3.511>
- Altayb, H. N., Ibrahim, A. M., Al-Hindi, R. R., Alharbi, M., & Wali, A. N. (2022). *In-vitro* and *in-silico* antibacterial activity of *Azadirachta indica* (neem) methanolic extract and identification of beta-D-mannofuranoside as a promising antibacterial agent. *BMC Plant Biology*, 22(1). <https://doi.org/10.1186/s12870-022-03650-5>
- Alzohairy, M. A. (2016). Therapeutics role of *Azadirachta indica* (neem) and their active constituents in diseases prevention and treatment. *Evidence-Based Complementary and Alternative Medicine*, 2016, 1–11. <https://doi.org/10.1155/2016/7382506>
- Brás, A., Guimarães, D., Silva, R., & Oliveira, R. (2024). Effect of bacteriophages against biofilms of *Escherichia coli* on food processing surfaces. *Microorganisms*, 12(2), 366. <https://doi.org/10.3390/microorganisms12020366>
- CBC/Radio-Canada. (2018, November 21). Here's why lettuce keeps getting contaminated with *E. coli*. *CBC News*. <https://www.cbc.ca/news/health/lettuce-e-coli-contamination-1.4913956>
- Cordery, A., Palmer, A., & Jenkins, K. (2018). Antimicrobial activities of essential oils, plant extracts and their applications in foods: A review. *Journal of Agriculture and Environmental Sciences*, 7(2). <https://doi.org/10.15640/jaes.v7n2a9>
- Edris, A., et al. (2021). Extract of *Neem (Azadirachta indica)* leaf exhibits bactericidal effect against multidrug resistant pathogenic bacteria of poultry. *Veterinary Medicine and Science*, 7(5), 1921–1927. <https://doi.org/10.1002/vms3.511>
- Food and Drug Administration. (2020, May). 7 tips for cleaning fruits, vegetables. <https://www.fda.gov/consumers/consumer-updates/7-tips-cleaning-fruits-vegetables>
- FoodSafety.gov. (2021, April 20). Safe ways to handle and clean produce. <https://www.foodsafety.gov/blog/safe-ways-handle-and-clean-produce>
- Guimarães, A. C., Meireles, L. M., Lemos, M. F., Guimarães, M. C. C., Endringer, D. C., Fronza, M., & Scherer, R. (2019). Antibacterial activity of terpenes and terpenoids present in essential oils. *Molecules*, 24(13), 2471. <https://doi.org/10.3390/molecules24132471>
- Hamadou, B., Njintang, Y. N., Mbofung, C. M. F., & Tatsadjieu, N. L. (2020). Influence of physicochemical characteristics of neem seeds (*Azadirachta indica* A. Juss) on biodiesel production. *Biomolecules*, 10(4), 616. <https://doi.org/10.3390/biom10040616>

- Herrera-Calderon, O., et al. (2019). *Azadirachta indica*: Antibacterial activity of neem against different strains of bacteria and their active constituents as preventive in various diseases. *Pharmacognosy Journal*, 11(6S), 1597–1604.
<https://doi.org/10.5530/pj.2019.11.244>
- Hirsch, J. (2019, February 8). Washing your greens won't protect against *E. coli*. *Consumer Reports*. <https://www.consumerreports.org/e-coli/washing-greens-protect-e-coli/>
- Jimenez Rios, H., et al. (2024). *In vitro* effectiveness of an aqueous extract of neem (*Azadirachta indica* A. Juss) leaves on bacteria causing healthcare associated infection in Valledupar. *Vitae*.
<https://revistas.udea.edu.co/index.php/vitae/article/view/341266/20804460>
- Leite, A., et al. (2022). From the environment to the hospital: How plants can help to fight bacteria biofilm. *Microbiological Research*, 261, 127074.
<https://doi.org/10.1016/j.micres.2022.127074>
- Mahmoud, G. A.-E., et al. (2024). Unveiling the neem (*Azadirachta indica*) effects on biofilm formation of food-borne bacteria and the potential mechanism using a molecular docking approach. *Plants*, 13(18), 2669.
<https://doi.org/10.3390/plants13182669>
- Meshari Ahmed Alhadlaq, M. A., et al. (2024). Overview of pathogenic *Escherichia coli*, with a focus on Shiga toxin-producing serotypes, global outbreaks (1982–2024) and food safety criteria. *Gut Pathogens*, 16(1). <https://doi.org/10.1186/s13099-024-00641-2>
- Mueller, M., & Tainter, C. R. (2023). *Escherichia coli* infection. *StatPearls*.
<https://www.ncbi.nlm.nih.gov/books/NBK564298/>
- National Research Council (US) Panel on Neem. (1992). *Medicinals*. National Academies Press (US). <https://www.ncbi.nlm.nih.gov/books/NBK234637/>
- National Research Council. (1992). *Neem: A tree for solving global problems*. National Academies Press. <https://nap.nationalacademies.org/read/1924/chapter/1>
- Ozone Biotech. (2025, February 27). Solving root rot in sugarcane: How neem products can help. <https://www.ozonebiotech.com/solving-root-rot-in-sugarcane-how-neem-products-can-help/>
- Petruzzello, M. (2019). *Neem | Description & uses*. *Encyclopædia Britannica*.
<https://www.britannica.com/plant/neem-tree>
- Prabu, S. L., Suriyaprakash, T. N. K., & Ruckmani, K. (2020). Investigation on the biofilm eradication potential of selected medicinal plants against methicillin-resistant *Staphylococcus aureus*. *Biotechnology Reports*, 28, e00523.
<https://doi.org/10.1016/j.btre.2020.e00523>
- Prasad, S., & Aggarwal, B. B. (2011). *Turmeric, the golden spice*. CRC Press/Taylor & Francis. <https://www.ncbi.nlm.nih.gov/books/NBK92752/>
- Price, S. B., Wright, J. C., DeGraves, F. J., Castanie-Cornet, M. P., & Foster, J. W. (2004). Acid resistance systems required for survival of *Escherichia coli* O157:H7 in the bovine gastrointestinal tract and in apple cider are different. *Applied and Environmental Microbiology*, 70(8), 4792–4799. <https://doi.org/10.1128/AEM.70.8.4792-4799.2004>
- Syhadat, A., & Diningsih, A. (2022). Identification of specific gravity and solubility in ethanol from citronella oil. *Journal of Public Health and Pharmacy*, 2(1), 1–3.
<https://doi.org/10.56338/jphp.v2i1.3727>

Travert, B., et al. (2021). Shiga toxin–associated hemolytic uremic syndrome in adults, France, 2009–2017. *Emerging Infectious Diseases*, 27(7).

<https://doi.org/10.3201/eid2707.204638>

Winrock International. (n.d.). *Azadirachta indica* – Neem, a versatile tree for the tropics and subtropics. <https://winrock.org/azadirachta-indica-neem-a-versatile-tree-for-the-tropics-and-subtropics/>

World Health Organization. (2018, February 7). *E. coli*. <https://www.who.int/news-room/fact-sheets/detail/e-coli>

World Health Organization. (2019). *Estimating the burden of foodborne diseases*.

<https://www.who.int/activities/estimating-the-burden-of-foodborne-diseases>

Wylie, M. R., & Merrell, D. S. (2022). The antimicrobial potential of the neem tree *Azadirachta indica*. *Frontiers in Pharmacology*, 13, 891535.

<https://doi.org/10.3389/fphar.2022.891535>

Wylie, M. R., et al. (2022). *In vitro* antibacterial activity of nimbolide against *Helicobacter pylori*. *Journal of Ethnopharmacology*, 285, 114828.

<https://doi.org/10.1016/j.jep.2021.114828>

Zhao, K., et al. (2024). Terpenoids as principal bioactive compound of *Cissampelos oppositifolia* essential oils: Enhancing synergistic efficacy with conventional antibiotics. *Frontiers in Cellular and Infection Microbiology*, 14, 1481656.

<https://doi.org/10.3389/fcimb.2024.1481656>



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FruitPlast: Biodegradable Plastic from Fruit Peels

By Aryan Mohanty (BASEF Participant)

Abstract

FruitPlast explores biodegradable plastics made from banana, apple, and orange peels as sustainable alternatives to petroleum-based plastics. The peels, rich in pectin, cellulose, and starch, were processed into flexible bioplastic sheets and tested for strength, flexibility, and biodegradability. All samples decomposed within 3–10 weeks, burned cleanly, and floated in water, though they were mechanically weaker and more water-absorbent than conventional plastics. Apple peels produced the strongest material, while banana added flexibility. FruitPlast highlights how fruit waste can be transformed into eco-friendly materials.



Plastic waste is one of the world's most urgent environmental problems. Canada alone produces over 4 million tonnes of plastic waste each year, with less than 9% being recycled. In response, FruitPlast investigates the creation of biodegradable plastic using fruit peels - banana, apple, and orange - as a natural, sustainable alternative to petroleum-based plastics.

Fruit peels contain natural polymers like pectin, cellulose, and starch, which can be transformed into plastic-like materials. In this project, peels were dried, ground, and mixed with water, glycerol, vinegar, and cornstarch to form flexible bioplastic sheets. The resulting plastics were tested for strength, flexibility, transparency, biodegradability, and water resistance, then compared to commercial plastics.

The results were promising. All samples degrade within 3–10 weeks when buried in soil, whereas traditional plastics can take hundreds of years. FruitPlast also burned cleanly without producing harmful fumes, and it floated in water due to polarity, indicating environmental safety. However, it was mechanically weaker: while conventional plastic withstood up to 210–350 lb./in², the fruit-based plastic held only 2.0–6.0 lb./in². It also absorbed more water, which softened the structure over time. Among the samples, apple peels produced the strongest and most elastic bioplastic, likely due to their high pectin and cellulose content and turgor pressure, which gives plant cells structure. Banana peel plastics were more flexible, while orange peels produced brittle sheets. A combination of all three balanced these properties and showed the most consistent performance.

Beyond the science, FruitPlast emphasizes affordability and sustainability. Fruit is widely consumed in Canada - especially bananas - and peels are typically thrown away. Bananas cost just \$1.66/kg, making them cheaper than potatoes (\$4.54/kg), another bioplastic source. Considering that 3.6 million tonnes of food waste is produced annually in Ontario alone, FruitPlast presents a way to repurpose organic waste into something valuable (Kolisynek, 2021).

While the material still needs improvements in strength and water resistance, the project highlights the potential of household waste as a green material source. Future exploration may include reinforcing the bioplastics with natural fibers, using different food waste like potato starch or eggshell proteins, and adding biodegradable coatings.

FruitPlast is a step toward Canada's 2030 zero plastic waste goal and a move closer to a circular economy, where waste is transformed into innovation. With continued development, fruit peel bioplastics could become a viable, eco-friendly alternative in the global effort to reduce plastic pollution.

References

- Kolisynk, A. (2021). How Ontarians Can Combat Food Waste. *Community Climate Council*. <https://www.communityclimatecouncil.org/how-ontarians-can-combat-food-waste>
- Zhang, S., Cheng, X., Yang, W., Fu, Q., Su, F., Wu, P., Li, Y., Wang, F., Li, H., & Ai, S. (2024). Converting fruit peels into biodegradable, recyclable and antimicrobial eco-friendly bioplastics for perishable fruit preservation. *Bioresource Technology*, 406, 131074. <https://doi.org/10.1016/j.biortech.2024.131074>



Producing Organic Liquid Nitrate Fertilizer using a Homemade Bioreactor System

By **Arsiema Fentabil**

Canada Wide Science Fair Silver Winner, Top Junior Project



Abstract

Many consider organic products to be healthier than those produced by chemical fertilizers. Using a homemade bioreactor system, two clean organic liquid fertilizers from dog and cow droppings were compared. The system has two units: an ammonification unit and a nitrification unit. In the ammonification unit, dog or cow droppings are degraded under anaerobic conditions, producing ammonia in gas form. The ammonia is carried out by jet air and introduced to the nitrification unit, where nitrifying bacteria convert the ammonia into nitrate, the primary nutrient required for plant growth. The fertilizer produced from dog droppings has higher amounts of nitrate. The fertilizers were tested successfully by growing plants.

Introduction

Between 2002 and 2022, the overall volume of solid waste sent to landfills in Canada increased by 11% (2.5 million tonnes). The problem is that most of this waste contains reusable things, such as animal droppings. Many may deem this useless, but it is actually a resource. Dog and cow droppings were used to determine if they could produce an effective liquid fertilizer.

Did you know that some farmers put manure directly on their plants as fertilizer? While this method could cause multiple problems, such as global warming, lack of control over nutrient absorption and nutrient amounts, water pollution, bacteria and pathogens, it also offers significant benefits. The high amounts of nutrients in manure, particularly nitrogen, make it a valuable fertilizer for plant growth.

The project will benefit farmers, and anyone interested in growing plants. If farmers were to use the liquid fertilizer, their products would be organic, as they would be grown without synthetic fertilizers. This liquid fertilizer, derived from droppings, is made with readily available resources, is environmentally sound, and budget friendly. Making synthetic nitrate fertilizers requires high temperatures and pressure, making them extremely energy intensive.

If the fertilizers produced by the bioreactor were to be used worldwide, in addition to producing food, it could significantly decrease waste and contribute to the fight against global warming. When droppings are left untreated, they release nitrogen in the form of nitrous oxide, a potent greenhouse gas. By converting these droppings into a useful resource, we can reduce these harmful emissions and their impact on the environment.

Hypothesis

It was hypothesized that dog droppings would produce a better nitrate fertilizer than dog droppings. Dogs eat more protein than cows, as they eat kibble while cows eat grass. Undigested protein is the number one cause of high nitrogen levels in droppings.

Method

The research was conducted from January through April 2025 and was primarily based on past experiments with cow manure. To ensure the credibility of my sources, information was cross-referenced from multiple reputable sources, including government sites and books.

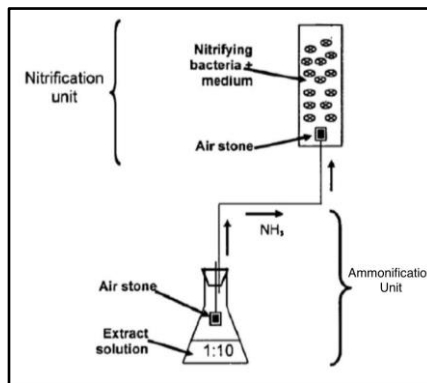


Figure 1 : The Bioreactor System

Inspired by Amit Gross's design, the bioreactor system consisted of ammonification and nitrification units. The ammonification unit is a repurposed laundry detergent container connected to an air pump. (Figure 1) A tube connects the

container to a clear pipe, which serves as the nitrification unit. The ammonification unit contains a 1:10 ratio of cow droppings to water. The nitrification unit consists of nitrifying bacteria and plastic beads. The exact process was repeated for the dog droppings. For the base of my experiment, an old-school desk was used. These materials were used as part of a material reuse and repurposing strategy.

The fertilizers were tested daily using water test strips, taking one sample each. Understanding that nitrifying bacteria and the degradation process are favoured at high temperatures, consistent temperatures of 25°C - 30°C were maintained in a small room with a space heater. The exact temperature was not critical, as the experiments were conducted side by side. When collecting the cow and dog droppings, it was ensured they were fresh and from the same time frame, minimizing ammonia loss.

For the final phase of my experiment, the fertilizers were tested by growing nine basil plants. Three plants were grown using the "cow fertilizer," three with the "dog fertilizer," and the remaining three without fertilizer. To ensure reliable results, any influencing variables were strictly controlled. Specifically, the pots, soil, amount of soil, seeds, and water were kept consistent for all plants and placed to receive equal amounts of sunlight.

Results

Within the innovative bioreactor system, organic nitrogen in the droppings becomes volatilized into gaseous ammonia (NH_3) as the degradation progresses. This process is known as ammonification, which occurs in the ammonification unit. The resulting ammonia is then carried by jet air to the nitrification unit, housing both ammonia-oxidizing and nitrite-oxidizing bacteria. The ammonia-oxidizing bacteria convert the ammonia into nitrite (NO_2^-), which is further transformed into nitrate (NO_3^-) by the nitrite-oxidizing bacteria. This sequence of conversions is termed nitrification.

Think of this process as making tea. When preparing tea, water and spices are boiled together, similar to how droppings and water are mixed in the bioreactor, resulting in ammonia. Once the spices have fully infused the water, it resembles what would be the case when no more nitrogen (released as ammonia) is left to be volatilized. The tea is then drained to extract all the spices. In the same way, the product (ammonia) is carried by jet air to the nitrification unit, leaving little to no nitrogen in the ammonification unit. The tea is bitter without sugar or honey. Similarly, plants do not like ammonia; they like it in the suitable form for plant growth - nitrate. The nitrifying bacteria work together to convert the ammonia to nitrite, then nitrate. When this happens, it is like a plant's equivalent of drinking a warm cup of tea.

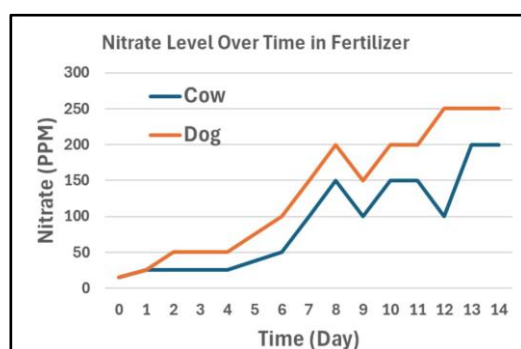


Figure 2 : Tracking Nitrate Levels

After my 14-day experiment, it was discovered that the fertilizer produced from dog droppings had a significantly higher nitrate concentration than that produced from cow droppings. At no point in the experiment did the nitrate concentration of the "dog fertilizer" fall below that of the "cow fertilizer." The "cow fertilizer" reached a final nitrate concentration of 200 ppm, while the "dog fertilizer" surpassed 250 ppm. This higher nitrate concentration in the "dog fertilizer" indicates a more effective fertilizer for plant growth. It is worth noting that the testing strips (max 250 ppm - nitrate) that were used were designed for fish tanks, indicating that the actual nitrate concentration could be even higher. (Figure 2)

The higher nitrate levels in the "dog fertilizer" are likely a result of the higher protein in their diet. The dog's diet consisted of kibble and meat, which are both high in protein. On the other hand, a cow's diet consists primarily of grass and oats, which contain lower amounts of protein.



Figure 3 : Plant Growth

The preliminary results of the basil growing show a clear visual difference between the control and plants treated with fertilizer. All plants treated with either fertilizer are visually better than the control. Furthermore, the "dog plants" are noticeably bigger and have more leaves than the "cow plants." They are also taller. (Figure 3)

The "dog plants" leaves are a richer green, indicating higher nitrate levels. These visual differences provide a compelling demonstration of the effectiveness of the "dog fertilizer". (Figure 4)

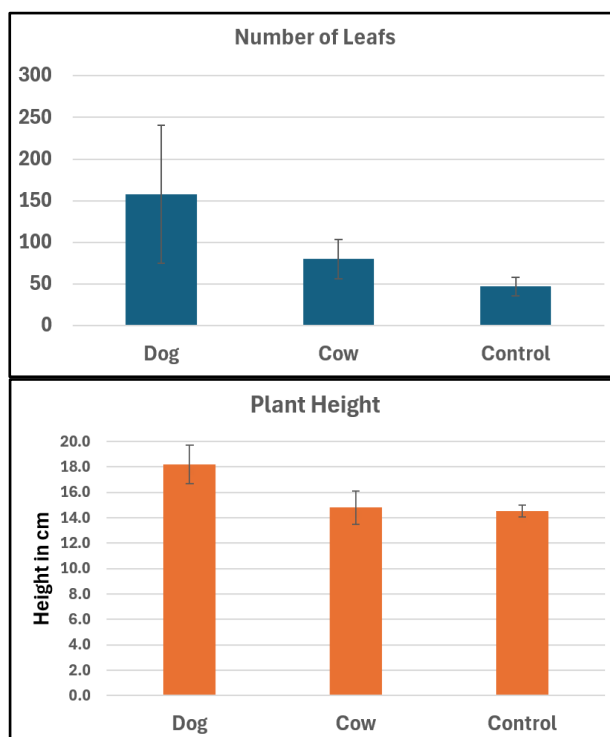


Figure 4 : Number of Leafs and Plant Height

Discussion

Based on the data, the fertilizer produced from dog droppings was better than that produced from cow manure. This is due to the higher amounts of nitrogen found in dog droppings. However, the preliminary results show that both fertilizers promote plant growth.

This demonstrates how the resulting liquid fertilizer can be a game-changer in agriculture. As mentioned previously, if farmers were to utilize this fertilizer, their products would be organic. This means that the prices will be slightly higher, which in the long run will pay for itself and even bring in additional profits. The reason behind this is its simplicity; the only equipment that requires electricity is the pump, which is not energy intensive. Furthermore, if farmers adopt this system, they would not have to add nitrifying bacteria more than once as they rest on the beads. The bacteria do this because the beads have high surface area. Another benefit for farmers is that converting these droppings into fertilizer eliminates all associated risks.

One consistent problem was the sudden decrease in the testing strip readings. Although they would return to normal in a day, it was not possible to completely determine if they were misreadings from the strips. In the future, it would be advisable to partner with a commercial lab to obtain more accurate results.

An expansion of the experiment would include testing animal droppings commonly found in my area, such as deer droppings. It would also be worthwhile adding a unit to capture the escaping ammonia from droppings.

Conclusion

In conclusion, liquid nitrate fertilizer produced from dog droppings is more optimal for plant growth than fertilizer produced from cow droppings, thereby supporting my hypothesis. This is likely due to dogs' diets containing more protein than that of cows.

This method can serve as a model for innovative waste management practices, demonstrating how communities can utilize local resources for agricultural purposes. Additionally, this approach enhances crop production and contributes to a more sustainable economy. This experiment not only compares cow and dog droppings when making liquid fertilizer but also represents a significant advancement in sustainable agriculture that benefits both farmers and the environment.

References

- BBC. (2021, June 3). *The world's forgotten greenhouse gas*. <https://www.bbc.com/future/article/20210603-nitrous-oxide-the-worlds-forgotten-greenhouse-gas>
- Florida Department of Agriculture and Consumer Services. (2020, November 11). *Aquarium water quality: Nitrogen cycle*. <https://www.fdacs.gov/Consumer-Resources/Recreation-and-Leisure/Aquarium-Fish/Aquarium-Water-Quality-Nitrogen-Cycle>
- Government of Manitoba. (2009). *Manure nutrients and their behaviour in soil* [Fact sheet]. https://www.gov.mb.ca/agriculture/environment/nutrient-management/pubs/mmfm_manurenutribehaviour_factsheet.pdf
- Gross, A. G. (2007). *Nitrogen extraction from organic wastes for fertigation in organic agriculture* (U.S. Patent No. 20070101783). Justia Patents. <https://patents.justia.com/patent/20070101783>
- Gross, A., Guy, O., Posmanik, R., & Fine, P. (2012). A novel method for combined biowaste stabilization and production of nitrate-rich liquid fertilizer for use in organic horticulture. *Water, Air, & Soil Pollution*, 223(3), 1205–1214. <https://doi.org/10.1007/s11270-011-0921-6>
- Miracle-Gro. (2023, March 24). *How to grow basil*. <https://miraclegro.com/en-ca/how-to-grow/how-to-grow-basil.html#:~:text=Plant%20basil%20in%20a%20spot,basil%20from%20going%20to%20seed>
- Multitanks International. (2020, September 3). *Everything you need to know about liquid fertilizers*. <https://www.multitanks.com/en/blog/everything-you-need-to-know-about-liquid-fertilizers-n86>

Smart Tech in Mobility: Connecting Cities and People

By Cameron Matloubi

STEM for Good Innovator, BioEndeavor Student Researcher



Abstract

Vehicles do not exist in isolation, but exist within larger systems, such as cities. Vehicles need to shape future city design. In the quest for efficient mobility, there is a role for smart technology that connects our cities, vehicles and even our homes. In this paper, I will explore the use of Internet of Things (IoT) technology and artificial intelligence,

comparatively analyzing the use of this technology by Tesla, BYD, and Mercedes-Benz.

Introduction

Automobile manufacturers are increasingly innovating to enhance the overall driving experience, ensure the safety of the driver, design for sustainability, elongate the life of a vehicle through creative servicing options, and manage the end-of-life aspects of vehicles.

Each manufacturer is pursuing varied options when it comes to this innovation. Take for example three trustworthy, popular vehicle brands from different countries, Tesla, BYD, and Mercedes-Benz. Tesla is one of the most technologically advanced vehicles on the market. Tesla uses technology in simple and creative ways, from adjusting the temperature, to making service appointments all on your infotainment screen. In the quest to enhance the driver's experience, Tesla uses its app to enable full control of the vehicle. Like Tesla, BYD can actually drive by itself using the autonomous driving feature. This requires that the passenger fully trusts that the car can indeed drive safely. Lastly, Mercedes-Benz introduces yearly advancements of new technology and safety features to ensure that the vehicle is safe and secure. Mercedes-Benz uses Internet of Things (IoT) in several ways such as the automated parking assist, distance cruise control, which involves vehicle to vehicle communication based on traffic flow, as well as changing lanes if needed to overtake vehicles.

Automotive manufacturers are increasingly designing their vehicles with more than the driver's experience in mind. In this paper, I will describe each vehicle and their different technological advances, with a focus on smart technology such as IoT and artificial intelligence (AI). The goal is to review how these features are being used to not only support the driving experience and efficiency, but also how they are supporting the transition to the green economy.



The Driver's Experience

In terms of vehicle experience, all three vehicles have their own distinct way of making sure their customer is satisfied with the uniqueness and authenticity of their vehicle. For convenience purposes, all three of these vehicle brands as well as other brands, have websites for you to personally

build your own car, choose specifications to your desire, purchase the car and even have the finished product delivered to your home to ensure a stress-free experience.

Tesla: Tesla's vehicles have been the most popular in terms of autonomous driving and smart adaptations. Once you sit in the vehicle, the simplistic environment encourages the driver to focus on enjoying the driving and infotainment features it has to offer. Tesla is known to be a sporty vehicle brand, in which some models can go from 0-60mph in two seconds. This can attract customers to purchase a vehicle with both speed and cutting-edge technology. For several years, Tesla has consistently advanced its self-driving features with its Autopilot feature by simply typing in an address on the navigation system, and having the car drive you there with minimal intervention by the driver. It can even respond to traffic signals, people as well as animals crossing the road. Tesla is continuously trying to develop a fully autonomous vehicle which involves many over-the-air updates. With this development, Tesla is among the most advanced vehicles. While observing the number of people interested in this feature, Tesla has increased the price option for this feature rapidly. With all this technology, Tesla must ensure the strict quality control of and response time of their vehicles, especially when people's lives are at stake. Tesla's brake assist acts with and without autopilot as well, to ensure the vehicle stops on time in case the driver does not. Tesla's "maintenance" is done over the infotainment system, with over the air updates. Tesla, being an electric car, aligns with the goals of a sustainable city, as well as limits gas station congestion particularly with the convenience of superchargers around the city and at home chargers. Time is money, and waiting at the gas station is a time sink. Drivers can set their vehicles to charge during the off-peak, night hours, to be assured their vehicles are fully charged by morning. Tesla is trying as best as they can to build more superchargers in busy cities, and even parking structures. As of today, there are always spots on the ground floor of parking structures that are specially reserved for Tesla or clean air vehicle owners. Tesla's commitment to sustainability is well known due to their renewable energy resources produced in their Gigafactories. This can attract consumers to purchase their cars for the benefit of a sustainable future (How Tesla Enhances Customer Experience (CX) Through Innovation and Customer-Centricity, 2024).

BYD: BYD is a practical car brand for all sorts of work, as BYD also offers electric trucks. It is similar to Tesla with the infotainment experience. From a large touch screen, the driver can control everything they want the car to do just from the infotainment system. This vehicle records driving habits to ensure the driver is having the most relaxed experience while driving. Based on renewable energy resources, BYD is equally supportive of building transportation that is aligned with the vision of the sustainable city. Customers can charge their vehicles at home with their fast charging. These partnerships with various companies are beneficial to produce faster chargers around the world.

This vehicle is very beneficial for transportation around colleges with their electric bus system and autonomous public transport. This will reduce noise and pollution in the campus - promoting then more sustainable environments. BYD excels in their driving assistance features, such as the lane keeping assist, active cruise control, and brake assist to prevent accidents. The cruise control with lane keeping assistance will keep a safe distance from the car in front as well as save battery while doing this - keeping the car at a constant speed. The Advanced Driving Assistance Systems ease the tension of the driver with mild active lane keeping assist and distance cruise control.

The AI powered autonomous driving demonstrates technological excellence with level 5 autonomous driving. BYD saves their buyers from the hassle of repair costs, with an extensive care warranty for the battery and driving components, which are the most valuable parts across the vehicle's life. With recording driving habits, the vehicle can also ensure good mileage for charging. On a full charge, this vehicle can do approximately 300 miles on a full charge. Additionally, the vehicle knows when maintenance is required by observing the battery and mileage using the embedded computer technology and avoiding unexpected breakdowns. These zero emission vehicles will attract the consumer driving the car. BYD minimizes waste by having recyclable batteries (How BYD Enhances Customer Experience (CX) Through Electric Vehicle Innovation, 2024).

Mercedes: Finally, Mercedes-Benz has always been the pinnacle in luxury and driving experience. The MBUX system learns from the main driver and records their habits in the vehicle and saves their profile so that once they enter the vehicle, all their previous entries are saved. The AI in the vehicle can indicate if it is a special calendar day and perform animations in the infotainment screen. This makes the driver feel that this is not just a car. From the minute you sit inside this vehicle, your information, voice, and habits are recorded to save time and energy for the driver and have their commands followed instantly. If the vehicle has multiple drivers, you are able to have your own profile on the Mercedes-Benz app. Remote start, door lock/unlock, and vehicle status checks, all using your iPhone (via Mercedes me connect), is the next level technology that transfers your phone information and requests to the vehicle. Another feature that is used from the app is if you enter a parking garage, you can get dropped off right in front and have the car park itself wherever it finds an open space and come right back to you to pick you up, using its self valet feature for its luxury models. This vehicle brand has increased security, with 360 degrees guard protection around the vehicle. Security features include a passcode for whenever you enter your vehicle before driving is permitted, which can then change the ambient lighting, the seating position, the air circulation, temperature, and other programmed features that correspond to the driver's profile. With the use of "Hey Mercedes", your personal assistant, drivers can command the car to take several actions from turning on the seat heater, to opening the panoramic sunroof. This assistant has been designed to be human-like because it not only responds to commands but can have a mini conversation with the driver. These human-like interactions add to the driver's experience.

The emergency braking feature consists of a camera surrounding the entire vehicle, to make sure there are no collisions. You can change your setting if you want the braking assist to warn early or late so the driver can be fully in charge of the process. It will even tell the driver if the car thinks it needs a break from driving for long periods of time. When driving for long periods during a trip, the seat kinetics feature constantly moves the seat lightly on the back and the thigh to prevent straining and support blood flow.

As a safety feature in case of a vehicular collision, the car raises up slightly so that if the vehicle collides from the sides, the collision will impact the strongest part of the car which is underneath the doors, keeping the driver from being severely injured. While driving, your vehicle's blind spot assist may signal that it's safe to change lanes. If needed, the vehicle's evasive steering assist activates to automatically guide the driver back into the original lane to avoid a potential collision. What could have been a life-altering moment is prevented by intelligent safety technology designed to react faster than human reflexes.

This seamless blend of AI and driver assistance highlights how advanced systems can significantly enhance road safety. Finally, Augmented Reality Navigation will use the front camera of the vehicle and show a real-world video of what is going on outside and include arrows to show exactly where the driver must turn, to prevent drivers from missing their route. AI plays a role in this by connecting the cameras and the navigation to present a real-world display of the outside world. Mercedes-Benz has been trying to make their vehicles more sustainable by adding a 48V mild hybrid to their entry level vehicles, and a mild hybrid system to their high-performance AMG's. By limiting the number of cylinders, this will ensure less pollution (How Mercedes-Benz Elevates Customer Experience (CX) with Luxury In-Car Technology and Personalized Dealership Services, 2024).

IoT and Connectedness

Automobile manufacturers are continuously enhancing their vehicles to accel in IoT. Each of these vehicles will perform in a way to become a part of the smart city, as stakeholders strive to achieve more of the U.N. Sustainable Development Goals. These vehicles interact with each other to adapt to the smart city, in order to ensure a seamless driving experience. As an example, traffic control systems can provide real-time data collected from connected cars to avoid traffic jams and accidents - mapping out routes for the driver. Tesla, BYD, and Mercedes-Benz are making their vehicles so that the driver can not only connect to other vehicles on the road, but also their homes. Drivers increasingly want to stay connected to their homes while driving, including through the use of internet-enabled smart devices, such as lights, home security systems, automatic garage doors, and more. (The Internet of Things (IoT) in the Automotive Market: Driving the Future of Transportation, 2023) Drivers may want to open a garage door and to turn on a light from the dashboard of their vehicles or through voice control when they are a certain distance from their home. These features will increasingly become standardized in vehicles. All home IoT devices that could be integrated together in a unified platform control include: a robotic cleaner, an air conditioner, refrigerator, lighting, temperature control, and automatic parking control system. Vehicles can similarly connect to home

infotainment systems, with drivers able to control their cars in the comfort of their own home with the possibility of green vehicles powering homes on an emergency basis. Additionally, IoT plays a role in the smart city when determining driving safety when it comes to weather conditions such as having another vehicle of the same brand in front alerting the driver of the vehicle behind it to prepare for the unprecedented conditions ahead beyond alerting the driver of general vehicle and driver movements. This will ensure that the driver does not get startled by the sudden changes of weather patterns. Each of these vehicles present their IoT connectedness in their own ways, and their uniqueness is how they will be able to adapt to the smart sustainable city (The Internet of Things (IoT) in the Automotive Market: Driving the Future of Transportation, 2023).

Tesla: Tesla approaches their connectedness differently by automatically responding to home functions based on proximity. If your vehicle is near your house, it prepares everything for you, from opening your garage to setting the temperature. This enhances the driving experience, making them feel relaxed and ready to rest after a long day at work. In case of an emergency, Tesla vehicles will inform you if there is something going on inside your house that needs immediate attention. Your car will connect to the security system in order to access this, if you add this in the “options” category of the vehicle system. These Tesla functions can also benefit the family, allowing for control of the oven or other kitchen systems. You can preheat your oven or turn on the stove so your food can be ready sooner when you arrive home (Tuerk, 2019).

BYD: The way BYD ensures their connectedness is through the use of their enhanced technology system in their vehicles. The BYD DiLink System is the software which controls the vehicle’s navigation, infotainment, and safety systems, making the driver control all the functions from their touchscreen. BYD’s technology, similar to that of an iPhone, gives the consumer various functionalities for entertainment and safety. In addition, the BYD over the air updates provide the driver with the latest technology to enhance the experience. Autonomous driving is also becoming more prominent in all vehicles. BYD is enhancing their self-driving capabilities with Level 4 and Level 5 driving, which can initiate a full self-driving feature. All BYD vehicles are equipped with smart assistance, navigation, and voice recognition to make the driver feel supported on their journey. Using the app itself, you can control the vehicle however you like and make sure the battery levels, air conditioning status, and tire pressures are sufficient enough for the journey you will be taking. With the help of the BYD app, drivers can locate their vehicle via the online map, and make sure their vehicle is prepared for their expectations upon entering, with all the climate controls set to their personal preferences. BYD vehicles, such as the V2G-enabled BYD ATTO 3, are starting to enhance their “Mobile Power Station” technology to act as a power source for the home. By using V2L outputs, this futuristic vehicle can supply energy back to power devices or the home. You can also plug in various items if you are on a road trip. This is an effective strategy by BYD to attract drivers to purchase their vehicles (Sheikh, 2024).

Mercedes-Benz: With the MBUX smart home function, the driver can easily control their home. The MBux smart home function supports numerous devices including lights, smart plugs, electrical appliances, thermostats, motion detectors, and garage doors. Smart home accounts for the devices can be linked to the user's MBux profile. In order to prevent road distraction for the driver, they can simply speak to their personal assistant, "Hey Mercedes", and their commands will be obeyed without delay. The authentication mechanism of Mercedes-Benz vehicles ensures only authorized users can obtain access to these home appliances. The MBux Voice Assistant also allows users to check home motion detectors from their vehicle, helping drivers with managing the security of their homes (Rogerson, 2023). The vehicle also has access to home cameras so that drivers can be informed if there is any motion detected, in case of any emergency. All of this comes at no additional cost to the driver; the only action needed to be taken is having your car connected to your phone via Mercedes connect or using the QR code in the central display and scan it with the driver's smartphone.

The Future of Automotive Technology

The future Human-Car Interface (HCI) will transform how people interact with vehicles, to create personalized, smart experiences driven by state-of-the-art technology. The role of cars is evolving beyond simple transportation and will be driven by smart technology and sustainability.

From infotainment displays to self-driving, slowly, the human machine interface will dominate all vehicles, and BYD, Tesla, and Mercedes-Benz are no exception. With all these self-driving capabilities that many vehicles have to offer, accelerators and brakes are slowly transitioning to become wired functions connected to the vehicle's technology systems, rather than the job of the driver. Increasingly, the vehicle's braking, accelerating, and steering have become the responsibility of the vehicle to ensure the driver will be safe. Tesla's autopilot is a perfect example of this with Tesla constantly transforming their vehicles into fully self-driving machines. Introduced a few years ago, vehicles include several screens in their vehicles to enhance the passenger's experience. With the M-Byte technological display, passengers can enjoy their experience as well, operating their screens to their liking, without disturbing the driver. For example, if YouTube were to be functioning on the passenger screen, it would blur a certain angle so the driver would not be able to look, preventing distraction from the road, ensuring both shared and private ridership. In addition to enhanced displays, vehicle cameras do more than just look for obstacles and prevent collisions. They also scan for the driver's physical state. For example, if the driver yawns, the vehicle will send a recommendation to find a rest area to take a break. If the driver seems to be dozing off, the vehicle can take control and lead the driver to the closest resting spot. Some of these enhanced systems are in the making, and some are already embedded in current vehicles as of 2025. These smart interfaces and technologies will save more lives each and every day while enhancing the driver's experience. From infotainment displays to decision-making cameras to fully operative vehicles, the world has transitioned to safer and more productive mobility with innovative ways for drivers to interact with their vehicles (Mann, 2020).

AI Assistants (Generative AI): AI is becoming dominant in the world, whether it is with vehicles, or just everyday life. Mercedes-Benz is starting to implement ChatGPT in their “Hey Mercedes” voice assistant to enhance the feedback provided to the driver. The voice assistant is not just programmed to Mercedes-Benz, but it will increasingly have an answer to everything the driver asks it. Having this type of responsive voice assistant will enable the driver to feel that “Hey Mercedes” is a real-life human assistant, just like we have today at the office. The value is in the connection of the car with the wider world, and with that ability, to plan forward and holistically generate usefulness in the world (Gen AI in high gear: Mercedes-Benz leverages the power of ChatGPT, 2023).

Augmented Reality (AR) Displays: Augmented reality plays a large role in navigation. With 3D and live images of the road, the opportunity exists for the driver to know what to do when wanting to merge to another road. With augmented reality head-up displays, the driver does not have to look down at the infotainment screen or the instrument cluster to view their speed, instead they can just look at their windshield in front of them. Augmented reality is used for vehicle design as well, lessening the cost of physical materials. Using special glasses designed for augmented reality, the vehicle components overlay diagrams directly on the vehicle which can improve efficiency and lessen errors (Understanding Augmented Reality in Automotive Technology, n.d.).

Brain-Computer Interfaces (BCI): Vehicles are increasingly becoming connected to the human brain. There are many vehicles which have removed the common functionalities that used to be required to drive and have transitioned into minimalistic controls and placements of the hand, which then connects to the human brain, and controls the vehicle in such a way that there is no need for an accelerator and brake. For example, the Mercedes-Benz Vision AVTR is a representation of the Avatar movie, in which the person will place their hand on a pad, and if they want the vehicle to go forward, they will simply push the pad in the forward direction. Braking, turning, and stopping are all done with the same control. This vehicle uses brainwaves to react to the person’s response. Using the Brain-computer interface, the vehicle can perform many different functions by just reacting to brainwaves. Today, we experience similar functionalities when we speak to ourselves, and the voice assistant automatically provides the best information or functions, but now, there will be no need to even speak; just the thoughts are important enough to manage your entire vehicle (Adams, 2021).

Computer Vision and Driver Emotion Detection: Emerging automotive technologies are increasingly focusing on the emotional connection between the driver and vehicle. Mercedes-Benz’s Vision AVTR concept embodies this shift by merging biometric feedback and brain-computer interface technology, allowing the car to respond to the driver’s thoughts and gestures, creating a seamless human-machine link (Mercedes-Benz, n.d.). Affectiva’s emotion AI leverages real-time facial analysis to monitor driver emotions and levels of distraction or fatigue, enhancing road safety by enabling vehicles to respond to the driver’s mental state (McManus, 2017). Together, these innovations are paving the way toward emotionally intelligent, responsive vehicles that enhance both user experience and safety.

Technology	Key Features	Examples and Applications
Infotainment Displays & Smart Interfaces	Transition of vehicle functions (braking, accelerating, steering) to automated, technology-driven systems. Integration of multiple passenger and driver screens for safety and entertainment. Includes driver monitoring systems that detect fatigue or yawning and recommend rest.	Tesla's Autopilot self-driving capabilities; BYD and Mercedes-Benz infotainment systems; M-Byte display that blurs passenger screen angles to prevent driver distraction.
AI Assistants (Generative AI)	Integration of generative AI for intelligent voice assistance, enabling natural conversation and information support. Enhances vehicle connectivity and driver engagement.	"Hey Mercedes" voice assistant powered by ChatGPT to provide dynamic, human-like responses.
Augmented Reality (AR) Displays	AR overlays real-time navigation and driving data directly onto the windshield, allowing drivers to focus on the road. Also used in vehicle design to reduce material costs and errors.	AR head-up displays for live 3D navigation; AR glasses for vehicle component visualization.
Brain-Computer Interfaces (BCI)	Vehicles connect directly to human brain signals for control. Traditional controls (pedals, steering) are replaced by handpads or thought-based inputs. Vehicles respond to brainwaves and gestures.	Mercedes-Benz Vision AVTR, inspired by Avatar, uses brainwaves to control movement (forward, braking, turning).
Computer Vision & Driver Emotion Detection	Uses cameras and emotion AI to monitor driver attention, fatigue, and emotions. Enables vehicles to respond adaptively, improving safety and emotional connection between driver and car.	Affectiva's emotion AI for facial analysis; Mercedes-Benz Vision AVTR combining BCI and biometric feedback.

Table 1: The Future of Automotive Technology

Discussion

As automotive technology advances, manufacturers are prioritizing user interface (UI) designs to create personalized, seamless experiences - such as voice assistants, infotainment systems, and biometric integration. However, geopolitical tensions are influencing consumer choice, with many countries considering support for domestic automakers. At the same time, global emissions are putting pressure for the adoption of electric vehicles. These policy shifts are creating consumer and other stakeholder backlash, particularly where charging infrastructure does not exist or jobs are at risk. As the industry transforms, there is rising demand for new careers and skills, especially in AI, data science, and green energy systems, highlighting the need for education and training to future-proof the automotive workforce (Agrawal, n.d.).

References

- Adams, R. D. (2021). *Mind-controlled cars? This brain-computer interface could transform driving*. TechRepublic. <https://www.techrepublic.com/article/mind-controlled-cars-this-brain-computer-interface-could-transform-driving/>
- Agrawal S. (n.d.). *Future of work in the automotive industry*. Binmile. <https://binmile.com/blog/future-of-work-in-the-automotive-industry/>
- EV Life. (n.d.-b). *What is bidirectional charging?* EV Life. <https://www.evconnect.com/blog/what-is-bidirectional-charging>
- Fowler, S. (2025, August 21). *BYD Atto 2 electric car review*. Independent. <https://www.independent.co.uk/cars/electric-vehicles/byd-atto-2-electric-car-review-b2693488.html>
- Ignitec. (n.d.). *IoT in the automotive industry: Driving the future of connectivity and efficiency*. Ignitec. <https://www.ignitec.com/insights/iot-in-the-automotive-industry-driving-the-future-of-connectivity-and-efficiency/>
- IoT Business News. (2023, October 13). *The Internet of Things (IoT) in the automotive market: Driving the future of transportation*. IoT Business News. <https://iotbusinessnews.com/2023/10/13/54422-the-internet-of-things-iot-in-the-automotive-market-driving-the-future-of-transportation/>
- Kaur, M., Kaur, S., & Varsha. (2022). *Internet of things in the smart automotive sector: A review*. In *2022 11th International Conference on System Modeling & Advancement in Research Trends (SMART)* (pp. 296–301). IEEE. <https://doi.org/10.1109/SMART55829.2022.10047604>
- Kim, Y., Oh, H., & Kang, S. (2017). Proof of concept of home IoT connected vehicles. *Sensors*, 17(6), 1289. <https://doi.org/10.3390/s17061289>
- LinkedIn. (n.d.-b). *How IoT development is revolutionizing the automobile sector*. LinkedIn. <https://www.linkedin.com/pulse/how-iot-development-revolutionizing-automobile-sector-keytech-fi-pxolf/>
- Maan, N. (2020, October 3). *Automobile human-machine interface (HMI) trends*. LinkedIn. <https://www.linkedin.com/pulse/automobile-human-machine-interface-hmi-trends-nakul-maan/>
- McKinsey & Company. (2023, September 13). *Gen AI in high gear: Mercedes-Benz leverages the power of ChatGPT*. McKinsey & Company. <https://www.mckinsey.com/features/mckinsey-center-for-future-mobility/our-insights/drivers-of-disruption/gen-ai-in-high-gear-mercedes-benz-leverages-the-power-of-chatgpt>
- McManus, A. (2017, April 11). *Driver emotion recognition and real-time facial analysis for the automotive industry*. Affectiva. <https://blog.affectiva.com/driver-emotion-recognition-and-real-time-facial-analysis-for-the-automotive-industry>
- Podium. (n.d.). *Customer experience trends in the automotive industry*. Podium. <https://www.podium.com/article/customer-experience-trends-in-the-automotive-industry/>
- Renascence. (n.d.-a). *How BYD enhances customer experience (CX) through electric vehicle innovation*. Renascence. <https://www.renascence.io/journal/how-byd-enhances-customer-experience-cx-through-electric-vehicle-innovation>
- Renascence. (n.d.-b). *How Mercedes-Benz elevates customer experience (CX) with luxury in-car technology and personalized dealership services*. Renascence. <https://www.renascence.io/journal/how-mercedes-benz-elevates-customer-experience-cx-with-luxury-in-car-technology-and-personalized-dealership-services>

Renascence. (n.d.-c). *How Tesla enhances customer experience (CX) through innovation and customer-centricity*. Renascence. <https://www.renascence.io/journal/how-tesla-enhances-customer-experience-cx-through-innovation-and-customer-centricity>

Rogerson, S. (2023, October 3). *Mercedes-Benz links cars to smart homes*. IoT M2M Council. <https://www.iotm2mcouncil.org/iot-library/news/connected-transportation-news/mercedes-benz-links-cars-to-smart-homes/>

Sheikh, S. (2024, January 16). *How to power your home with vehicle-to-grid technology*. EV Life. <https://evlife.world/en/ae/tech/how-to-power-your-home-with-vehicle-to-grid-technology/>

Tuerk, M. (2019, October 30). *Tesla demonstrates the power of the Internet of Things*. Forbes. <https://www.forbes.com/sites/miriamtuerk/2019/10/30/tesla-demonstrates-the-power-of-the-internet-of-things/>



OctaFilter: A Novel, Low-Cost, Biomimetic Water Analysis and Electrolysis-Based Purification Device

By Ishan Kapadia

Ingenious Regional Winner, Greater Vancouver Regional Science Fair
Divisional Winner, BioEndeavor Student Researcher

Abstract

The OctaFilter project presents a low-cost, biomimicry-inspired approach to tackling water insecurity in low-income and rural communities by combining natural diagnostic indicators with a modular purification system. Using accessible materials such as turmeric, lettuce, onion skin, cellulose, and dandelion root, the device reliably detected contaminants like lead, heavy metals, bacteria, and organic pollutants with up to 95–100% accuracy in controlled trials. A gravity-fed filter layered with sand, moringa seed powder, cellulose, and activated charcoal, followed by a compact electrolysis chamber, achieved up to 88% heavy metal removal, 84% bacterial reduction, and improved water clarity and taste across 600+ tests. Designed with frugal science principles and 3D-printed for durability and modularity, the OctaFilter demonstrates how affordable, community-driven tools can bridge the gap between advanced laboratory methods and real-world water needs. Future work will focus on scaling the design, integrating smartphone-based analysis, and piloting systems in rural regions to empower local communities with sustainable access to safe drinking water.

Introduction

Access to safe drinking water remains one of the most urgent health and development challenges of the 21st century. In many low-income and rural communities, millions of families still lack reliable access to clean water, relying instead on unsafe wells, rivers, or rain collection [1]. The result is widespread disease, reduced quality of life, and barriers to education and economic progress. Existing approaches are often too costly, reliant on imported materials, or dependent on centralized infrastructure that is not feasible in remote regions. What is urgently needed are low-cost, community-driven methods that can be built with local resources and maintained sustainably, empowering villages and households to secure their own safe water supplies.

The OctaFilter project was created to meet this challenge by combining the principles of biomimicry and frugal science. Biomimicry looks to nature for proven strategies - such as plants that bind contaminants or surfaces that repel impurities - while frugal science emphasizes low-cost, accessible tools that anyone can build or adapt. The OctaFilter merges these approaches into a modular system capable of both detecting and purifying water contaminants. By relying on inexpensive, readily available inputs and simple engineering, the device demonstrates how communities can create point-of-use solutions that are effective, scalable, and adaptable to both classrooms and real-world environments.

Materials

The OctaFilter project relied on a combination of natural, low-cost ingredients and simple engineering components. For the water testing module, five household or plant-based materials were selected based on their chemical properties and accessibility: turmeric powder (lead detection) [2], red/purple lettuce (heavy metal detection) [3], onion skin (bacteria) [4], cellulose powder (organic pollutants) [5], and dandelion root (secondary heavy-metal detection) [6]. These materials were purchased in food- or laboratory-grade form to ensure consistency during testing, though each has potential for local preparation in resource-limited settings.

The water purification module was built around a gravity-fed, layered design using sand, moringa seed powder, cellulose powder, and activated charcoal. Each layer served a complementary role: sand for removing turbidity, moringa as a natural coagulant and antimicrobial [7], cellulose for fine particle capture [8], and activated charcoal for adsorbing chemicals, pesticides, and odors [9]. The final stage incorporated an electrolysis chamber powered by a basic low-voltage circuit. This setup used two stainless steel electrodes, a 9V battery, a battery connector, insulated wires, alligator clips, and a toggle switch. When connected, the system generates chlorine and hypochlorous acid directly in the water, providing effective disinfection with minimal energy input [10]. (Figure 1)

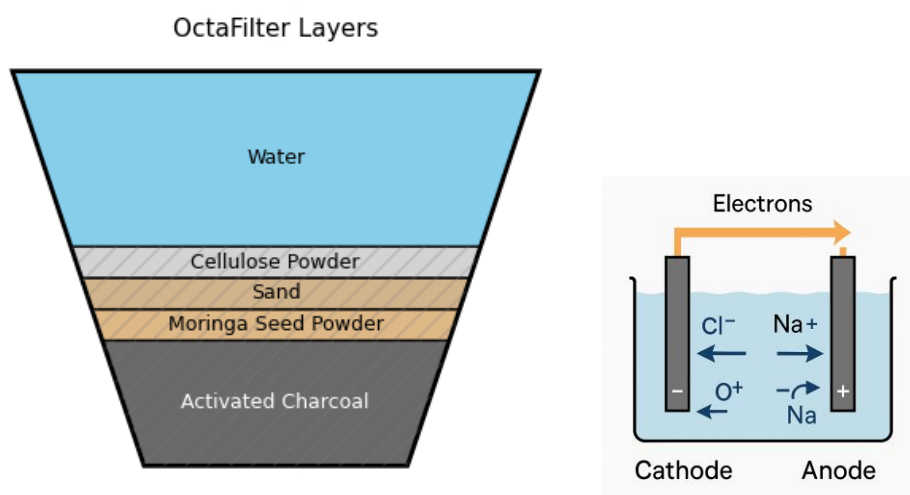


Figure 1: Layers of OctaFilter & Electrolysis Diagram

To house these components, the OctaFilter was 3D-printed using PETG filament, chosen for its water resistance, chemical stability, and durability under repeated use. PETG avoided the warping and chemical reactivity issues of PLA and ABS, making it the most practical option for a filter exposed to moisture, salt, and heat from electrolysis [11]. The modular, printed design allowed each chamber to be easily assembled, replaced, or modified, while keeping the overall production cost under CA\$6. (Figure 2)

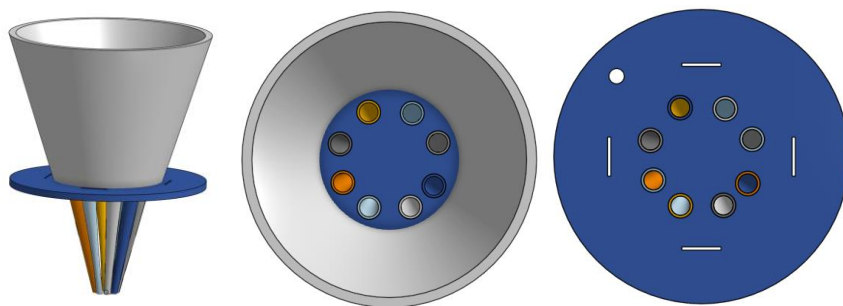


Figure 2: CAD Diagrams of OctaFilter

Methods and Approach

The OctaFilter project was developed in two complementary stages: water testing and water purification. In the testing module, I designed controlled experiments to evaluate how natural, low-cost materials could function as indicators for contaminants commonly found in unsafe water. Water samples were spiked with pollutants at internationally recognized safety thresholds, and potential indicators were added and observed for measurable responses such as colour changes, texture shifts, or clumping [12]. Each candidate was tested in over 50 trials across different concentrations and exposure times to calculate detection accuracy and consistency.

The purification module was designed as a gravity-fed, layered filter followed by a final disinfection step. Water passed through successive layers, each targeting a different class of impurities, before entering a small electrolysis chamber powered by a 9V battery and simple electrodes. This stage generated disinfecting agents directly in the water, providing protection against bacteria and viruses. Effectiveness was measured before and after treatment using pH probes, clarity scales, water-quality test strips, and biological indicators [13].

To maintain consistency during testing, food- and laboratory-grade materials were used. However, a guiding principle of the project was frugal science - ensuring the same methods could be adapted with locally sourced or prepared alternatives in real-world deployments. The modular design allows the system to remain scientifically reliable while being replicable in rural, off-grid, or disaster-relief contexts at a fraction of the cost of commercial devices.

Findings and Insights

Testing with simple, plant-based indicators showed that natural materials can reliably detect dangerous water contaminants. Turmeric powder detected lead at the international safety limit ($5 \mu\text{g/L}$) with 80% accuracy in 10 minutes and over 95% accuracy at higher concentrations. [14] Red/purple lettuce extract reacted to heavy metals like mercury and cadmium, achieving 100% detection at $300 \mu\text{g/L}$ within 30 minutes [15]. Onion skin membranes responded to bacteria by wrinkling or clouding, correctly detecting contamination 80% of the time after six hours and 95% at higher levels. Cellulose powder absorbed pesticides and organic pollutants with 90%

accuracy at 20 minutes, while dandelion root, though less reliable at 60%, provided a useful secondary confirmation method. These results demonstrated that frugal, biomimetic indicators can serve as first-line diagnostic tools in communities without access to advanced labs. (Figure 3)

For the water testing portion, samples were prepared with varying concentrations of specific impurities, including a distilled water control, two levels below the Maximum Acceptable Consumption (MAC), the MAC level, and two levels above it. Each sample was tested using the natural indicators, and results were compared across different exposure times between the reagent and the indicator. Since the higher exposure times consistently produced more reliable detections, those values were used for the rest of the testing and for the data visualized below. Results were recorded using Boolean values to indicate whether the indicator detected the impurity.

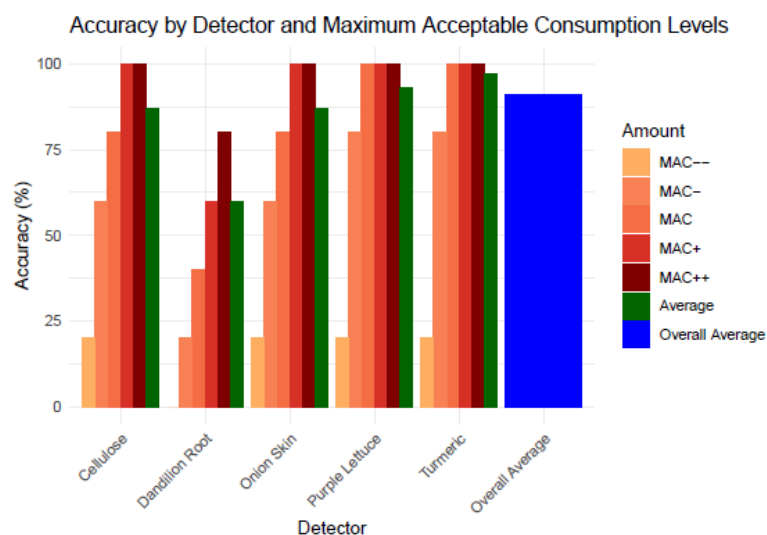


Figure 3: Accuracy of Indicators

For purification, the layered OctaFilter system showed strong performance across multiple contaminants. Sand removed turbidity, moringa bound suspended solids and microbes, cellulose improved clarity, and charcoal absorbed chemicals and odors before the final electrolysis step disinfected the water. Across 600+ controlled trials, the device achieved 84% bacterial reduction, 88% heavy metal removal, and 75% organic pollutant reduction. Average clarity scores rose from 2.1 to 4.7 (out of 5), the food dye was nearly eliminated, and pH stabilized around 7.1, close to neutral. The electrolysis chamber proved highly efficient, generating enough chlorine and hypochlorous acid to disinfect 500 mL of water in under two minutes.

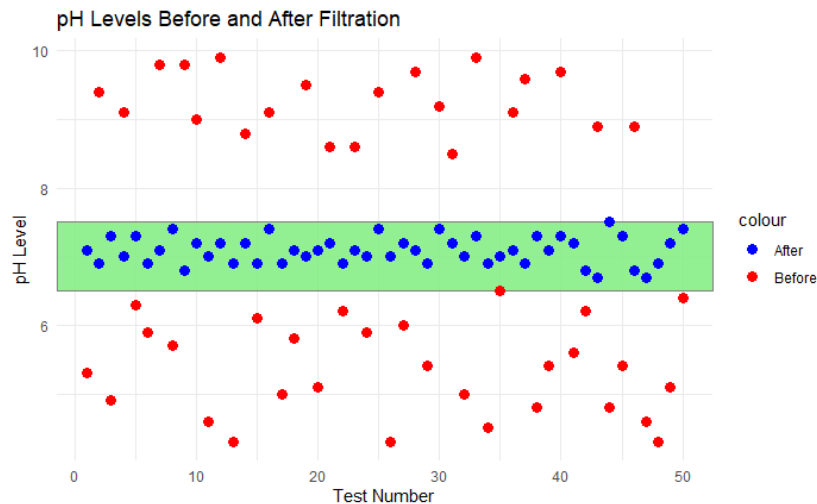


Figure 4: Ph Level Analysis

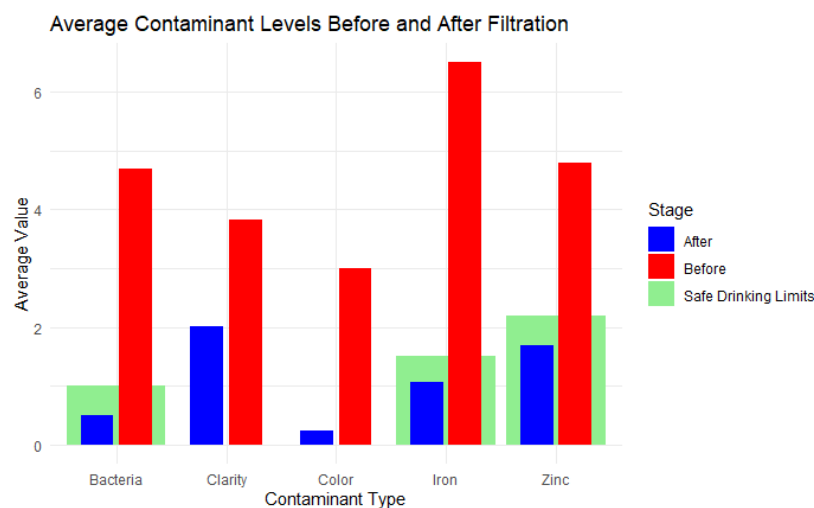


Figure 5: Contaminant Level Analysis

The combined results highlight the OctaFilter’s potential as both a diagnostic and treatment tool. By validating natural indicators with high detection accuracy and demonstrating purification that significantly improves clarity, safety, and taste, the system bridges a critical gap between laboratory methods and real-world usability. The fact that these materials are inexpensive and widely accessible reinforces scalability for off-grid communities, NGOs, and classrooms worldwide.

Future Directions

Moving forward, the OctaFilter can be refined to increase accuracy and scalability. On the diagnostic side, integrating smartphone-based image analysis could quantify colour changes from natural indicators, reducing subjectivity and making results more reliable. For purification, larger prototypes and community-scale units could be tested to evaluate flow rates and long-term durability under field conditions. Partnerships with NGOs are planned to distribute educational kits, enabling students to learn STEM concepts through hands-on water science. Long-term, the goal is to pilot OctaFilter systems in rural India and sub-Saharan Africa, empowering local women as water stewards and scaling the design into a global, low-cost solution for water insecurity.

References

1. World Health Organization. (2019, June 18). *1 in 3 people globally do not have access to safe drinking water – UNICEF, WHO*. World Health Organization. <https://www.who.int/news/item/18-06-2019-1-in-3-people-globally-do-not-have-access-to-safe-drinking-water-unicef-who>
2. Alahi, M. E. E., et al. (2018, July 26). Detection methods of nitrate in water: A review. *Sensors and Actuators A: Physical*. Elsevier. <https://www.sciencedirect.com/science/article/abs/pii/S0924424718307830>
3. Bai, H., et al. (2024, April 24). Microfluidic sensors for the detection of emerging contaminants in water: A review. *Science of the Total Environment*. Elsevier. <https://www.sciencedirect.com/science/article/abs/pii/S004896972402881X?via%3Dihub>
4. Calvo-López, A., et al. (2018, July 26). Detection methods of nitrate in water: A review. *Sensors and Actuators A: Physical*. Elsevier. <https://www.sciencedirect.com/science/article/abs/pii/S0924424718307830>
5. Martinez, A. W., et al. (2008, December 16). [Article title]. *Proceedings of the National Academy of Sciences (PNAS)*. <https://www.pnas.org/doi/10.1073/pnas.2216789120>
6. Liang, M., et al. (2023, November 13). Paper-based microfluidic chips for food hazard factor detection: Fabrication, modification, and application. *MDPI*. <https://www.mdpi.com/2304-8158/12/22/4107>
7. Huang, Q.-T., et al. (2024, April 20). Exploring the impact of dissolved organic matter on nitrate. *ACS Publications*. <https://pubs.acs.org/doi/10.1021/acs.jchemed.3c00958>
8. Williams, A. (2016, May 1). Inspired by nature: Water treatment technology innovations. *WaterWorld*. <https://www.waterworld.com/home/article/16202085/inspired-by-nature-water-treatment-technology-innovations>
9. Charcoal House. (2025, January 27). *Activated charcoal for water filters*. https://charcoalhouse.com/activated-charcoal-for-water-filters/?srsltid=AfmBOoqxYDsaqF9OvaMsVWTWdpDhlOsD50SHH22nNsDwnQ7OmR1_bjcM
10. Backer, H., & Hill, V. (2024). Water disinfection. *Centers for Disease Control and Prevention*. <https://wwwnc.cdc.gov/travel/yellowbook/2024/preparing/water-disinfection>
11. He, Y., et al. (2016). 3D-printed paper-based microfluidic analytical devices. *Micromachines*. MDPI. <https://www.mdpi.com/journal/micromachines>
12. Chen, J. L. (2024). Advances in microfluidic paper-based analytical devices (μPADs): Design, fabrication, and applications. *Wiley Online Library*. <https://onlinelibrary.wiley.com/doi/10.1002/smt.202400108>
13. Ahmed, A. S., et al. (2022, October 13). High surface area activated charcoal for water purification. *MDPI*. <https://www.mdpi.com/2504-477X/6/10/311>
14. Chu, J. (2021, March 25). MIT engineers make filters from tree branches to purify drinking water. *MIT News*. <https://news.mit.edu/2021/filters-sapwood-purify-water-0325>
15. Sims, A. (2018, June 12). Ditch your water pitcher and use a burnt stick instead. *Architectural Digest*. <https://www.architecturaldigest.com/story/ditch-your-water-purifier-activated-charcoal-sticks>



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AI And Tech for Good: AI In The Classroom and Sparks Of Innovation

“Most of all, Gratify (my invention) is a promise. It is a promise that small things matter and that we can teach ourselves to notice them. It is a promise that people deserve tools that treat them with respect and warmth. And it is my promise to keep building, keep listening, and keep trying to make the internet a place where gratitude has a voice. If you try Gratify and it helps you remember one tiny, good thing in your day, then everything I did was worth it.”

Sean Onwuzurike

How Do Teachers Differentiate AI Writing from Authentic Writing?

By Emily Mineault, Junior Editor IJSGI

Canada Wide Science Fair, Bronze Winner, BioEndeavor Student Researcher



Abstract

Artificial intelligence (AI) is a type of technology that gives computers and machines the ability to do things that are commonly done by humans, such as creating art, playing games, and writing. In recent years, AI has started to gain popularity in schools, with many students using AI to write essays for them. The purpose of this experiment was to survey teachers and test how (and if) they can differentiate AI writing from authentic student writing. Not only is it cheating to have AI write essays as school assignments, but it can also be dangerous and detrimental to society. In the future, many theorize AI usage in schools being a much bigger issue than it already is, especially if teachers cannot identify it (Merod, 2025).

Introduction

In recent years, AI has become very popular, especially in schools. Many tend to wonder whether or not teachers can tell the difference between AI and student written essays. A lot of students don't think teachers can; however, many believe it varies. This project was designed to test whether teachers would be able to identify AI writing, and what their strategies are for doing so.

Although universities have measures in place to prevent and stop AI use, most middle and high schools do not. If a student begins using AI at a young age, they will find ways to use it as they grow older (Lewsen, 2023). This project was not only testing whether or not teachers can differentiate AI writing, but also how they do so, to see common strategies used among teachers, and which of these strategies are reliable and which are not. Though this project is mainly focused on AI in schools, it can lead to conversations about other areas of AI use in society, and how it affects our world (Onder, 2025).

Hypothesis

Spelling and grammar are more commonly used to identify AI-generated student writing. Teachers who look at spelling and grammar to identify AI-generated essays than other more complex strategies, are more likely to struggle with correctly identifying AI-generated essays.

Prompt engineering can be used to enhance the complexity and human qualities of the essays.

Method

Student essays were acquired by contacting students in grades six to twelve asking if they would want to participate in the project. Teachers were also emailed to ask if they would be willing to partake. ChatGPT then created all of the AI essays with the help of prompt engineering. The ratio of student to AI essays was six to three. Did you know that in the USA, 1 out of every 3 young adults/college students use ChatGPT regularly?

This is why there was a ratio of 1 AI essay for every 3 student essays. After all the essays were acquired, they went into a Google Form. After one week, there were 16 responses. The teachers' answers were then analyzed to determine how many AI essays were correctly identified, how many student essays were correctly identified, and the teachers' strategies for detecting AI.

Sample Essays Used

Student Essays	ChatGPT Generated Essays
Though the music industry is full of amazing artists and musicians, it is clear that Taylor Swift is the greatest of all time when it comes to writing and performing music. Her talent is unmatched by all other artists, and her music is truly a masterpiece. She began writing music when she was only eleven years old, and since that time she has released eleven albums, with over 250 songs. She has won fourteen Grammys, four of which being Album of the Year awards. Not only is she a talented songwriter, she is also an incredible showman and performer. Her Eras Tour, which lasted two years, still consumes the hearts of Swifties around the world. On this tour, she performed for three hours with complicated dances, quick changes, and beautiful visual and special effects. During the two years in which the Eras Tour was active, over 10 million people attended her tour. She performed in rain and extreme heat, rarely cancelling shows. She performed throughout major moments in her life, such as breakups and backlash from fans. She is also known to be a very outgoing person. Many people who have met her say that she is a very kind person, which is represented in the many donations and volunteer work she does in her community. In autumn of 2024, she donated \$5 million to Feeding America,	Greek mytholgy is a bunch of stories from old Greece about gods, heros, and monstors. People used to tell these stories to explain things like why it rains or why people feel mad or hapy. Zeus is the king of all the gods, and he controls thuder and lightning. His wife, Hera, is the godess of marraige, but she was always mad at Zeus becuase he had other girlfriends. One heroe is Odysseus. He went on a big adventur after the Trojan War and had to fight a big monstor called the Cyclops, and almost died from some singin monstors called sirens. Theres also the Minotaur, a half-man, half-bull monstor. A heroe named Theseus killed it with a plan. He was very brave! Greek myths are full of cool storie that people still tell today, and they are in movis and books.

and in 2024 she donated over \$6.5 million to charity and nonprofit organizations. At the 2025 Grammys, Taylor Swift was seen sharing her seat with Cynthia Erivo, who was not able to find her own. At the Grammys, Taylor Swift is often seen clapping and standing for everyone who wins, and dancing along while others perform. Ultimately, Taylor Swift is the G.O.A.T. in the music industry, with her many accomplishments and successes supporting this fact.	
Climate change is long term shifts in temperature and changes weather patterns, it occurs because workers burn fossil fuels, these fossil fuels include coal, oil and gas. Other ways climate change occurs is from greenhouse gas and cutting down trees (when trees are cut down they release the carbon they have been storing because forests collect carbon dioxide.). Climate change has many effects like hotter temperatures and more droughts and even increases the severity of storms and rising sea levels. Humans have been the #1 cause of climate change for more than 100 years dating back to the 1800s. Climate change does not just affect humans but they also affect wildlife as well, the increased temperatures can trigger the collapse of fragile ecosystems and can cause huge waves of extinction. There are also animals that have gone extinct like the Black Softshelled Turtle, the Hawaiin Crow, the Wyoming Toad and sadly many other species. If you are wondering how you can put in a small effort to stop climate change for good you can save energy at home by switching to LED light bulbs, washing your clothes with cold water, and instead of using a dryer to dry it out, use the sun. You should also stop using cars and try to use bicycles and public transport (specifically trains or Biofuel buses.). It may seem like a small action but can be a big step to end climate change.	Hockey is a fun and fast sport played on ice. Two teams of six players try to score goals by hitting a small rubber puck into the other team's net. Players wear skates and use sticks to move the puck around. The game is very fast, and players need a lot of skill to keep up. In a hockey game, there are three periods, each lasting 20 minutes. The team with the most goals at the end wins. Each team has a goalie who tries to stop the puck from going into the net. Players have to skate quickly, pass the puck well, and make fast decisions during the game. Hockey started in Canada in the 1800s. The first indoor game was played in Montreal. Since then, hockey has become really popular all over the world, especially with the NHL (National Hockey League) in North America. Hockey is also played in the Winter Olympics, where different countries compete for gold. People love hockey because it's fast and exciting. Fans cheer for their favorite teams, and players learn important things like teamwork and never giving up. Hockey is a fun sport to watch or play!
Music is something that is very important	Chocolate is one of the best treat ever! It's

to society. It has been around for at least 35,000 years, and is continuously progressing. There are many styles of music, such as rock, pop, country, and so many more! Music is also used as a way of expression. Both by making and listening to music, you can express yourself and your emotions. Along with being a form of expression, music is also something that affects our economy, as the global music industry makes billions a year. The industry employs thousands of people, and is worth billions of dollars. In conclusion, music is very important for our culture, emotional and social well being, and our entertainment.	sweet and comes in different types like milk, dark, and white chocolate. Milk chocolate is smooth and sweet, dark chocolate is bitter, and white chocolate is creamy. Chocolate comes from cacao beans that grow on tree's. Some people say chocolate makes you happy. Chocolate is in icecream, cookies, and brownies. It makes everything taste better. In conclusion, chocolate is delicious and makes people smile.
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Table 1: Sample Essays Used

Results

Out of the 16 teachers surveyed, not a single teacher was 100% correct. The highest score was 8/9, and the lowest was 2/9. Here is the list of how much was scored correctly by how many teachers. (Figure 1)

1/9: 0 teachers
2/9: 1 teacher
3/9: 2 teachers
4/9: 3 teachers
5/9: 3 teachers
6/9: 5 teachers
7/9: 1 teacher
8/9: 1 teacher
9/9: 0 teachers

What the teachers scored

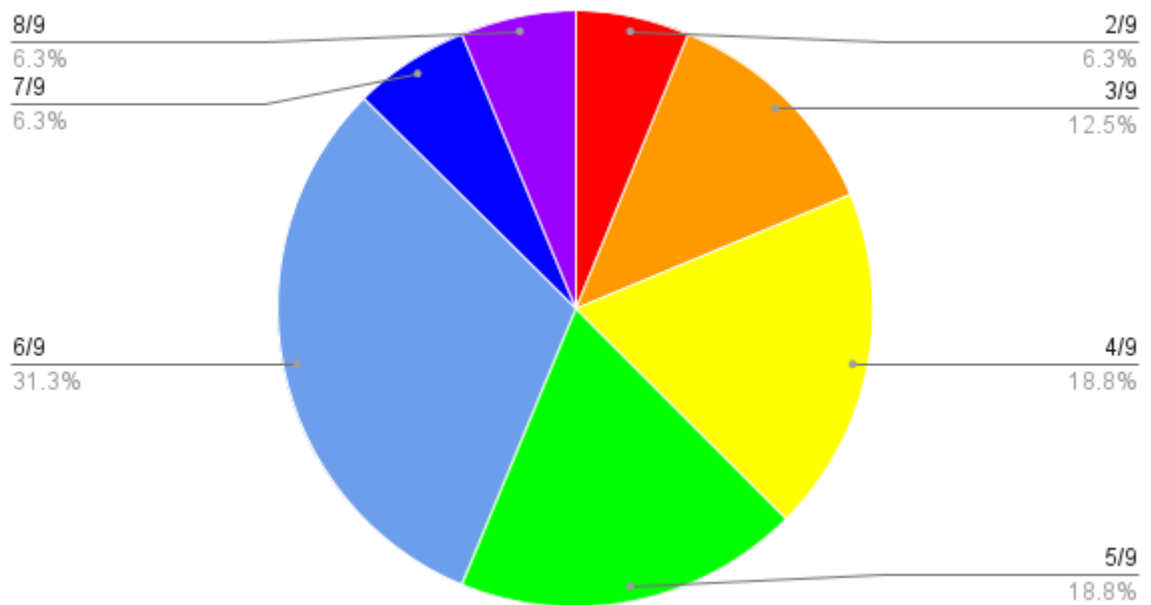


Figure 1: Teacher Scores

Some of the ways that the teachers identified the AI essays:

- Tone (mentioned 3 times)
- Vocabulary (mentioned 6 times)
- Spelling and grammar (mentioned 12 times)
- Sentence structure (mentioned 8 times)
- Organized structure (mentioned 2 times)
- Lacks a personal tone or perspective (mentioned 6 times)

The above shows how many times each strategy was mentioned by teachers when asked how they differentiate AI writing from student writing. As you can see, spelling and grammar were mentioned the most, being used as a strategy 12/16 times. Vocabulary was mentioned 6/16 times, and sentence structure was mentioned 8/16 times. (Figure 2)

Discussion: Prompt Engineering

Out of all the strategies used by teachers to differentiate AI writing from student writing, spelling and grammar was mentioned the most.

Spelling and grammar are more commonly used to identify AI-generated student writing. Teachers who look at spelling and grammar to identify AI-generated essays than other more complex strategies, are more likely to struggle with correctly identifying AI-generated essays.

Strategies for identifying AI

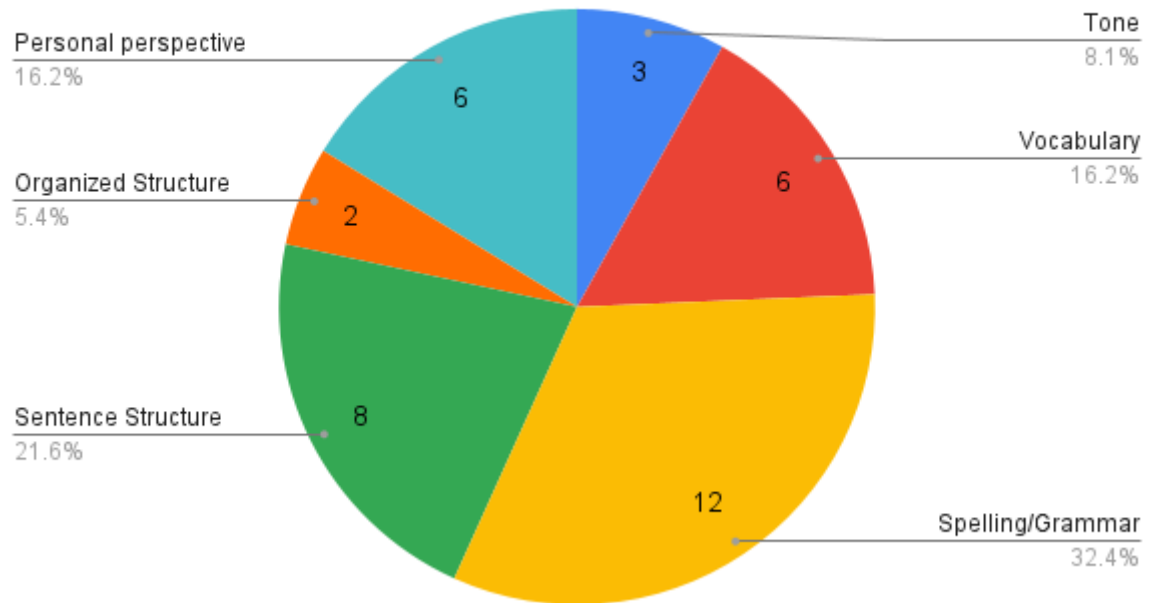


Figure 2: Strategies for Identifying AI

Prompt engineering can be used to enhance the complexity and human qualities of the essays.

Prompt engineering is the act of creating specific requests for AI LLMs (Large Language Models) in order for them to generate better results. There are many ways to do this: making sure the prompt is clear, providing context and background information, and even providing direct sources and links that the LLM can use. The more prompt engineering that is done, the better the AI essay will be. However, in this case, prompt engineering was used in order to make the essays sound more human. Phrases such as: “make it sound like something a student would write” and “add more grammatical errors” were incorporated into the prompt. This way, the AI would write as if it were a human. Because of prompt engineering, the AI essays sounded very human-like. Examples are included of three essays: one with no prompt engineering, one with minimal prompt engineering, and one with lots of prompt engineering. All were created by AI, however version three sounds much more human-like than version one. By using prompt engineering, we can see that looking at vocabulary and sentence structure is not a reliable way to determine if an essay is AI, since the AI can write with simpler language and change how it forms sentences.

Table 2: Using Prompt Engineering to Humanize Essays

Prompt Engineering Used	Essay
No prompt engineering	Prompt: Write me a short essay about food. Food is an essential part of human life, serving not only as a source of sustenance but also as a medium for culture, connection, and pleasure. At its core, food fuels our bodies, providing the necessary nutrients and energy to maintain health and vitality. But beyond this biological necessity, food plays a significant role in our social lives and emotional well-being. Culturally, food is deeply intertwined with tradition and identity. Every culture has its own unique dishes, ingredients, and methods of preparation that reflect the history and values of its people. From the spices of Indian curries to the pasta of Italy, food tells stories of migration, trade, and innovation. It brings people together, whether it's around a family dinner table or at a community celebration, fostering a sense of belonging and shared experience. Food also has the power to evoke emotions and memories. The smell of a favorite dish can transport us back to a special moment, like a holiday meal or a childhood gathering. These sensory experiences are often tied to feelings of comfort and warmth, providing not just physical nourishment but emotional fulfillment as well. In recent years, the conversation around food has expanded to include discussions on sustainability and health. As people become more aware of the environmental impact of food production and the importance of nutrition, there's a growing movement toward conscious eating. Choosing locally grown produce, reducing food waste, and opting for plant-based options are just a few ways people are aligning their food choices with their values. In conclusion, food is far more than a mere necessity for survival. It is a source of joy, culture, and connection, shaping our lives in ways both big and small. Whether it's a simple meal or a gourmet feast, food holds a special place in our hearts and minds, reminding us of the

	importance of sharing and savoring the moments that nourish us.
Minimal prompt engineering	Prompt: Write me a short essay about food and cultural cuisine and its effects on mental health, the media, and our lives. Food and cultural cuisine play a profound role in shaping our mental health, the media, and our daily lives. From the comfort of home-cooked meals to the global reach of culinary trends, food has far-reaching effects on both our well-being and how we perceive ourselves and others. Cultural cuisine, in particular, is a direct reflection of the history, values, and traditions of a community. The act of preparing and enjoying traditional dishes can foster a deep sense of identity and belonging, positively impacting mental health. For many, food connects them to their roots, offering emotional comfort and a sense of continuity. Sharing meals tied to cultural practices can reduce feelings of isolation, boost self-esteem, and foster a sense of pride in one's heritage. However, food also plays a significant role in the media, where it is often portrayed in ways that influence our perceptions and behaviors. Cooking shows, food blogs, and social media platforms such as Instagram have made food a central part of popular culture. While this can encourage creativity and appreciation for diverse cuisines, it also introduces pressures to conform to certain ideals of health, beauty, and success. The constant exposure to curated, "perfect" meals can lead to unrealistic expectations about food and body image, especially among younger audiences. This can contribute to anxiety and unhealthy relationships with food, potentially leading to issues like disordered eating. The effects of food on mental health extend beyond just emotional comfort. Research has shown that certain foods can impact our mood and cognitive function. For example, traditional cuisines that emphasize fresh, nutrient-dense

	ingredients—such as Mediterranean or Asian diets—are linked to better mental health outcomes and lower rates of depression and anxiety. In contrast, diets high in processed foods and sugars can contribute to mood swings and fatigue, potentially exacerbating mental health challenges. In our daily lives, food also plays a vital role in social interactions and community. Meals are often shared in family settings, at gatherings, and in celebrations, making food an integral part of human connection. These interactions foster communication, cooperation, and a sense of support, all of which are crucial for mental well-being. At the same time, food choices are becoming increasingly influenced by media trends, such as the rise of veganism or gluten-free diets, which can impact how we view nutrition and wellness. In conclusion, food is far more than just a means of survival; it is an essential element that affects our mental health, our cultural identity, and how we interact with the world. As the media continues to shape our perceptions of food, it's important to remain mindful of the psychological and emotional impacts these representations have on our lives. Embracing cultural cuisine, being conscious of media influences, and making food choices that nurture both body and mind can help create a balanced relationship with food that enhances our overall well-being.
Significant prompt engineering	Prompt: Write me a short essay about food and cultural cuisine and its effects on mental health, the media, and our lives. Make it very simple, and make it sound like a student wrote it. Add grammatical mistakes, simple vocabulary, and childish humour. Food is something that everyone needs, but it's also way more than just fuel for our bodies. Different cultures have different types of food, and that can really affect how we feel, think, and even how we see ourselves because of what we see in the media. First, cultural food is really important.

Each country or culture has its own special dishes, and these meals are often connected to family traditions or special celebrations. When we eat food from our culture, it can make us feel happy, safe, and like we belong somewhere. For example, I love eating my mom's pasta because it reminds me of family dinners, and it makes me feel cozy and not lonely. It's like a big hug for your stomach. When we share these meals with others, it can help us connect with people and feel less stressed.

But then there's the media, and oh boy, it's not always helpful. We see food all the time on TV, Instagram, and in magazines, and a lot of it looks perfect – like the fancy salads or smoothie bowls that make everyone look like they have their life together. This can make us feel bad about what we eat because we start

thinking we need to eat only healthy food to look good or be happy. This can mess with our heads and make us feel stressed or worried about how we look or if we're eating the "right" foods. It's like when you see a food blogger with their 10th pancake stack that looks way too perfect, and you feel like you're doing life wrong because your pancakes are just flat and sad.

Also, food affects how we feel inside. Some foods, like fresh veggies and fruits, can actually make us feel better and have more energy. On the other hand, eating too many sweets or junk food can make us feel tired or cranky. So, food is not just about taste, it's also about our brains! It's like when I eat too much candy, I get a sugar crash and feel kind of sad. Not fun. In conclusion, food is super important in our lives, not just because it keeps us alive, but because it can make us happy or sad depending on what we eat and how we see food in the media. It's important to enjoy the food from our cultures, but also to remember that food isn't about being perfect. It's about enjoying it, connecting with others, and not stressing over whether our pancakes look like the ones on Instagram. So eat what makes you happy, but maybe don't eat too much candy.

Conclusion

In the future, it would be very interesting to look at how AI detection is affected by a teachers' background, experience, and personal bias. Teacher bias can be incredibly damaging to a student's mental health and future success, since many students may experience stress and anxiety from receiving an AI accusation. It would also be very eye-opening to look at how teachers score after receiving AI detection training, since this can help us determine if AI training should be mandatory for teachers. It would also be very interesting to see how well online AI detectors work and how they compare to teachers when detecting AI essays (Topinka, 2024).

Though AI has become quite prevalent in schools, there are many ways education can use AI to empower students, which can help to prevent students from using AI to cheat. Rethinking evaluations would be a great way to prevent cheating. Instead of teachers assigning essays or research papers as final projects, perhaps an oral presentation or creative project could be an alternative. In conclusion, by addressing bias, improving AI detection methods, and rethinking assessments and evaluations, teachers can create an environment that uses AI as a tool rather than a threat to integrity.

References

- Ahmed, A. S., et al. (2022, October 13). *High surface area activated charcoal for water purification*. MDPI. <https://www.mdpi.com/2504-477X/6/10/311>
- Backer, H., & Hill, V. (2024). *Water disinfection*. Centers for Disease Control and Prevention. <https://wwwnc.cdc.gov/travel/yellowbook/2024/preparing/water-disinfection>
- Bai, H., et al. (2024, April 24). *Microfluidic sensors for the detection of emerging contaminants in water: A review*. *Science of the Total Environment*. Elsevier. <https://www.sciencedirect.com/science/article/abs/pii/S004896972402881X>
- Calvo-López, A., et al. (2018, July 26). *Detection methods of nitrate in water: A review*. *Sensors and Actuators A: Physical*. Elsevier. <https://www.sciencedirect.com/science/article/abs/pii/S0924424718307830>
- Charcoal House. (2025, January 27). *Activated charcoal for water filters*. https://charcoalhouse.com/activated-charcoal-for-water-filters/?srsltid=AfmBOoqxyDsaqF9OvaMsVWTWdpDhIOsD50SHH22nNsDwnQ7OmR1_bjcM
- Chen, J. L. (2024). *Advances in microfluidic paper-based analytical devices (μPADs): Design, fabrication, and applications*. *Small Methods*. Wiley Online Library. <https://onlinelibrary.wiley.com/doi/10.1002/smt.202400108>
- Chu, J. (2021, March 25). *MIT engineers make filters from tree branches to purify drinking water*. *MIT News*. <https://news.mit.edu/2021/filters-sapwood-purify-water-0325>
- He, Y., et al. (2016). *3D-printed paper-based microfluidic analytical devices*. *Micromachines*. MDPI. <https://www.mdpi.com/journal/micromachines>
- Huang, Q.-T., et al. (2024, April 20). *Exploring the impact of dissolved organic matter on nitrate ...* *Journal of Chemical Education*. ACS Publications. <https://pubs.acs.org/doi/10.1021/acs.jchemed.3c00958>
- Liang, M., et al. (2023, November 13). *Paper-based microfluidic chips for food hazard factor detection: Fabrication, modification, and application*. *Foods*. MDPI. <https://www.mdpi.com/2304-8158/12/22/4107>

- Martinez, A. W., et al. (2008, December 16). *PNAS*.
<https://www.pnas.org/doi/10.1073/pnas.2216789120>
- United Nations Children's Fund (UNICEF) & World Health Organization (WHO). (2019, June 18). *1 in 3 people globally do not have access to safe drinking water*.
<https://www.who.int/news/item/18-06-2019-1-in-3-people-globally-do-not-have-access-to-safe-drinking-water-unicef-who>
- Williams, A. (2016, May 1). *Inspired by nature: Water treatment technology innovations*. *WaterWorld*. <https://www.waterworld.com/home/article/16202085/inspired-by-nature-water-treatment-technology-innovations>
- Sims, A. (2018, June 12). *Ditch your water pitcher and use a burnt stick instead*. *Architectural Digest*. <https://www.architecturaldigest.com/story/ditch-your-water-purifier-activated-charcoal-sticks>

Gratify: Sparks of Innovation and Humanity

By Sean Onwuzurike

Canada Wide Science Fair Participant, Social Innovator



When I think back to how Gratify began, it feels like remembering a few bright moments stitched together into something that suddenly looked like more than just an idea. I have always been a happy person, but that did not mean I never struggled. I noticed my friends, people at school, and even strangers online carrying around a weight of stress, anxiety, and quiet

loneliness. Most of them did not have a place to say how they really felt without being judged. A lot of them, including myself, sometimes swallowed those feelings and kept going. That bothered me. I wanted to change it in a way that actually made sense for people my age and beyond.

The first spark was simple. I started writing down things I was grateful for. Not full essays, just tiny notes, drawings, or songs on my phone. Every time I did that, I felt calmer. The small stuff started to matter again. One night, after a week of doing it, I realized that the thing that helped me was not the words themselves, but the habit. The habit trained my brain to look for good moments. I wondered what would happen if more people had a friendly, easy tool to build that habit, something that felt more like a friend than an app. That question became the seed of Gratify.

Building Gratify was messy and brilliant and absolutely my kind of chaos. I did not have fancy design schools or stacks of money behind me. What I had was a clear idea and late nights. I sketched wireframes on paper, tested ugly prototypes, and reworked the flows until the app felt gentle to use. I picked Thunkable because it let me turn ideas into something I could actually open on my phone. I learned through videos, trial and error, and a lot of patience. I also reached out to people who knew more than I did. I got insight from mentors and researchers who pointed me to studies and features I might have missed. Their guidance helped shape the parts of the app that matter most.

From the start I wanted Gratify to be flexible. Not everyone wants to write long paragraphs. Teens especially do not always want that. So, I added ways to express gratitude that felt natural. You can write if that helps, but you can also draw a quick picture, record a voice note, add a song, or even create a tiny music log. I built a mood tracker that starts every session with a single emoji. That one small choice gives people a snapshot of how they are, and over time it becomes a map of feelings that they can actually understand. I organized Gratitude Genres so someone who feels stuck can open a category like Friendship and read tiny prompts or short ideas to help them notice the little things. I made Gratify social, because sharing a simple note like I am grateful for my sibling can make other people smile. I called that social space Gratify Connect.

One of the parts I am most proud of is Grati-Bot, the little AI companion I built into the app. I wanted it to feel human, not robotic. I trained it to respond with kindness and curiosity, to validate feelings, and to offer breathing exercises or quick prompts when someone is struggling. It was crucial that Grati-Bot sounded like a supportive friend, so I carefully tuned its voice and personality. Integrating an LLM was technical and challenging but seeing real conversations where Grati-Bot helped someone shift out of a spiral was worth every headache.

Testing Gratisfy with people changed me. I asked around and had roughly fifteen people try the app, mixing ages and backgrounds so the feedback would be honest. Watching someone open the app for the first time and take a breath was everything. Many of them preferred drawing or voice notes over typing. One person told me that sketching a small smile actually made them grin for the first time that day. Another said that reading a Gratitude Genre gave them a new idea to be thankful for, and it brightened their mood. Grati-Bot received messages like thank you, I needed that, and that kind of response reminded me why I started this.

This project taught me more than how to code or how to design a clean interface. It taught me why empathy matters in software. It taught me that technology can be gentle. It taught me that small, repeatable actions add up. I learned to listen better, to iterate faster, and to stay stubborn about the things that mattered to people. I also learned to accept help. Mentors, friends, and family kept me steady when I doubted myself.

Gratisfy is not finished. I want it to keep growing, to keep getting kinder and more helpful. I want to add better personalization, more meaningful community stories, and ways to celebrate progress that are not just points or badges but real, human moments. My dream is for Gratisfy to be a space where someone pauses, even for thirty seconds, and discovers something worth smiling about. If that helps one person feel a little less alone, then it is already doing its job.

Most of all, Gratisfy is a promise. It is a promise that small things matter and that we can teach ourselves to notice them. It is a promise that people deserve tools that treat them with respect and warmth. And it is my promise to keep building, keep listening, and keep trying to make the internet a place where gratitude has a voice. If you try Gratisfy and it helps you remember one tiny, good thing in your day, then everything I did was worth it.

A Matter of Access to Clean, Affordable Energy

By Niam Maharajh

BASEF Inspiration Award Winner

Abstract

The lack of affordable, clean energy solutions on the market have led to economic limitations, education constraints, and environmental and human health consequences. Clean and affordable energy sources that are portable are key to solving this multifaceted problem. Furthermore, the implementation of these technologies into the pre-existing habits of many rural populations in the global south, will allow the people who reside in such underprivileged geographies to source power without radically changing their way of life. Unfortunately, no mass-produced product has been developed and been introduced to such populations. As a result, the economic divide between developed and developing nations continues to grow.

One solution that may attenuate this muddle that humans have created, is the MagnaVolt, an electromagnetic axial flux flywheel inspired portable AC generator. While the idea of this generator sounds great, the practicalities make this product difficult to design, manufacture and mass produce, as the excessive coil windings and large magnets increase the product's total mass. Moreover, attempting to wind coils more efficiently and decreasing the number of magnets has led to a lower output voltage and current. Further research, development, and financing are required to elevate this product to produce more voltage without compromising the small size and a lightweight composition.

Introduction

Bikes are a prime source of transportation in the global south (Frey, 2024). Along with transportation benefits, riding offers mental and physical benefits to relieving manual laborers from their day-to-day troubles. With nonprofit organizations such as the Village Bicycle Project and the Reach Alliance, the population of people in Africa in particular, who have access to a bike, has increased dramatically. While the bicycle has traditionally been utilized to travel from point a) to point b), the mechanical rotation generated as a byproduct of its gear system and spinning wheels can be used to spin an electromagnetic generator, creating power where there is a need for power. This paper examines the importance of electricity with the empowerment of populations across the global south. The proposed approach to mitigate this issue is harnessing human power to generate electricity through a bicycle attachment system, using the spinning wheels and gears of a bike to spin an electromagnetic flywheel axial flux generator. The final product should provide sufficient power to charge an attached 21700 lithium-ion battery power bank, offering access to electricity in regions with limited grid access.

The development of infrastructure, the augmentation of quality of life and further progress across the U.N. sustainable development goals, in particular goal # 9, depends fundamentally on access to clean sources of power. Energy in the form of electricity powers innovation by creating light and by spinning fans so students can

learn comfortably, powering radios - allowing the distribution of knowledge and culture, electrifying modems, permitting internet access in remote locations, and stimulating communal economies by creating microgrids within local communities.

Theory

Electric motors convert electrical energy into mechanical energy, through the alternation of electric and magnetic fields. These motors operate through electromagnetism. Any motor can be made into a generator through reverse rotation; instead of electricity powering the motor to spin and to exert mechanical motion, mechanical motion is used to generate electricity. The MagnaVolt 5000 was built with a single-phase AC axial flux serpentine coil motor, meaning 1 large wound coil acts as the stator, and 32 magnets on either side of the stator (16 magnets on either side), act as the rotor.

Stator

The stator is the stationary part of the motor. In previous magnavolt generations, a 3 phase BLDC (Brushless direct current) motor was used in place of an BLAC (Brushless alternating current). The stator of a BLDC motor is primarily composed of stator teeth around the center core, copper wire is wrapped around these teeth in alternating directions, allowing an alternating electric current to be generated within the wires. For ease of manufacturability, the BLDC motor design was discontinued, and the AC motor was introduced allowing for the coils to be wound in a fraction of the time and improve the radial air gap in between the coils and the magnets, allowing for improved efficiency.

Rotor

The rotor, also known as the bell of the motor, is the alternating, rotating component of the motor. In the radial flux BLDC motor integrated into previous prototypes, the rotor is composed of neodymium magnets, facing the center stator in alternating polarities, being spun around the stator. These neodymium magnets are referred to as “poles”. The MagnaVolt 5000 is composed of 2 axial flux motors, where the stator and rotor(s) are situated on the same axis. This design allows for more space, resources and energy efficient organization, as more of the actual wire comes into contact with the magnets, and the radial air gap is decreased. Magnetic flux describes the motion of the rotor in a motor. As the magnetic field alternates, so does the electric field in the copper wire that has been wrapped around the stator. A steel shaft is connected to the inside of the rotor, so that the rotor is able to spin.

Stator mount

The stator mount doesn't do as much as the components previously described. This being said, it does hold the stator in its place during operation, and it holds the ball bearings so that the rotor's steel shaft is able to go through and the rotor is able to spin. The BLDC motor's design included an integrated stator mount that allowed for ease of handling when spinning the actual motor. Instead of a traditional stator mount, the stator mount on the MagnaVolt 5000 was unique to its bike application. Observers of the MagnaVolt design will notice that the stator mount is composed of 2 adjustable bracket arms separated 210 radial degrees from each other, and 15 degrees from the center circumference. This design permits for the application of this invention to different bike types and allows for ease of installation onto any bike.

The fundamental idea behind this generator is based upon Faraday's laws of induction and Alessandro Volta's equation on the electromotive force.

Faraday's Law of Induction, or $emf = -N(d\Phi/dt)$, describes how a changing magnetic field can exert an electric charge or electromotive force in a nearby conductor.

The electromotive force, or $e = Blvsin\theta$ describes how different physical factors within a generator influence a given generator's output voltage. The generator's flux density, in Tesla units, strength in magnets (described as B), the length of the conductor at right angles to the magnetic field, in meters, length of wire (described as l), and the velocity of the conductor, in m/s, how fast the generator is spinning, (described as v) and the angle in which the conductor cuts the magnetic field, ideally at 90 degrees, (described as θ), determines the total induced electromotive force in volts or output voltage, (described as e). Past prototypes of the Megavolts have been improved by increasing the strength of magnets, increasing the number of coils wound and increasing a gear ratio so the generator is able to spin faster.

Of course these variables: $Blvsin\theta$ can all be altered to decrease as well as increase the electromotive force and improve power output. From generation 2 to 3, more stator teeth were wound (therefore more windings), in addition, more magnets were installed, thus increasing voltage by a peak of ~ 4 volts.



Figure 1: Generation 4 of the MagnaVolt

Figure 1 displays generation 4 of the MagnaVolt series. This prototype is composed of 18 stator teeth, and 16 magnetic poles. The design was radial flux, and despite its small appearance, weighed over 4 pounds. The stators were wound with 30-gauge copper wire and had 350 windings of wire per tooth.

Layout

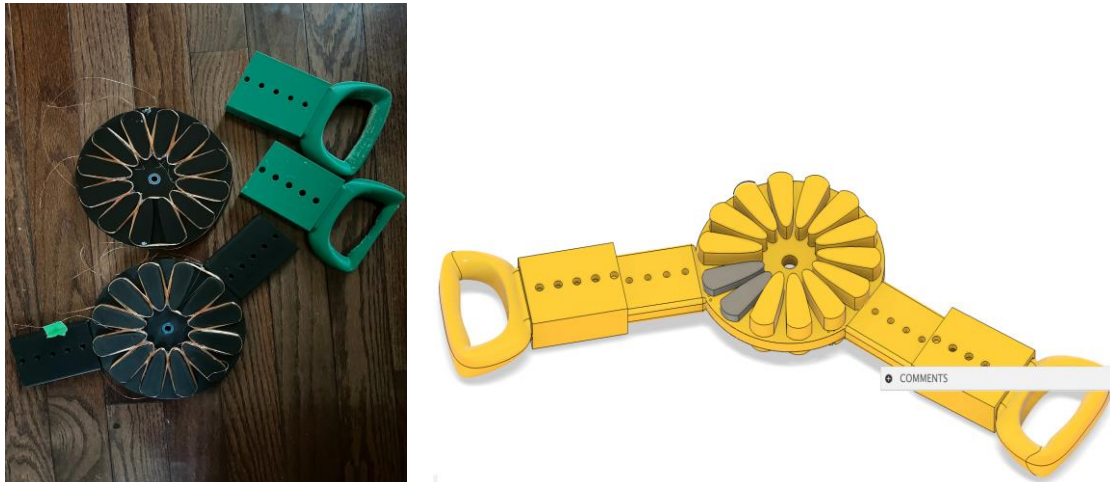


Figure 2: Stator and Stator Handles

Figure 2 shows the 2 stators that comprise this generator - that hold the 160 meters of 30-gauge copper wire. The 3D printed stators, and 2 handles, printed with PLA plastic and wound with copper (Left), and the stator originally designed on Fusion360 (Right), both play a crucial role in the production of electricity, as described in theory, above. The arms of the stator (printed in green), attach and are adjustable in relation to the actual stator via a M5 nut and bolt system. M5 bolts are placed into the aligning 5.2 mm holes, and attach the stator and arms together, creating a rigid composition that can attach to the bike frame with 5-inch metal hose clamps. The bolts themselves are then tightened with M5 lock nuts. This system allows the entire power generation setup to be adjustable and fit on virtually any standard bike.

As for the wire configuration, there are 4 coils of ~ 40 meters of wire, both stators have coils on either face in a serpentine layout to maximize the total cross-sectional area of the stators face.



Figure 3: Rotor System

Figure 3 is the rotor system, with each rotor printed from PLA plastic, and each rotor face composed of 14 N52 neodymium magnets, with alternating polarity. The rotors sandwich the stators with 4 faces of magnets, with the center rotor having 2 magnetic sides, as the 2 stators are situated on either side. The rotors are connected to the steel shaft (as seen above), with JB weld, allowing the entire rotor contraption to spin freely, and synchronously.

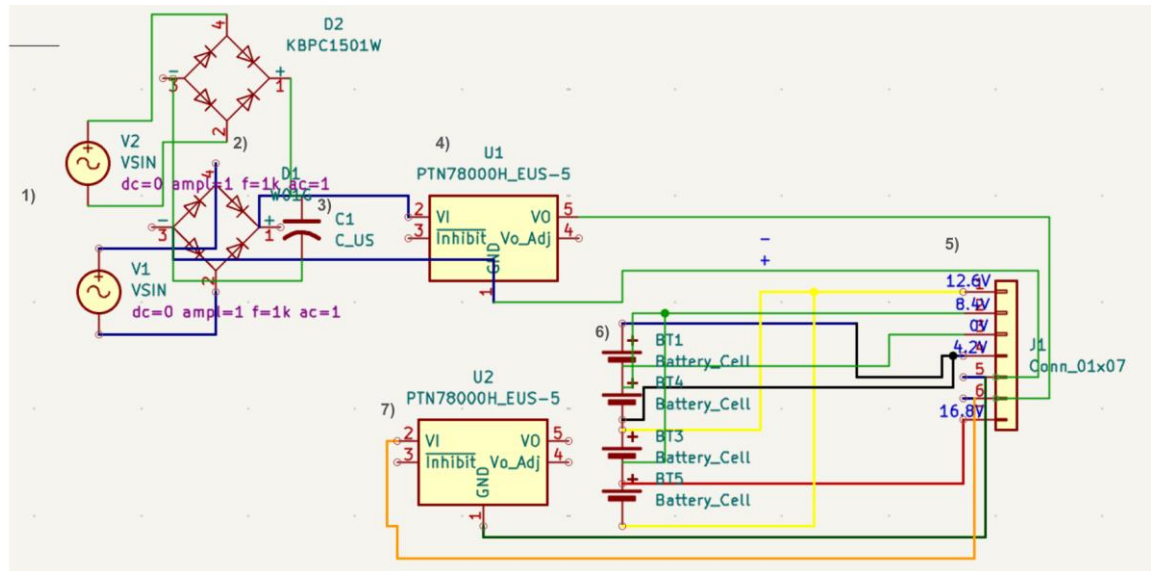


Figure 4. The Electronic Layout of the Power Generation System

Figure 4 is a schematic of the circuitry used in this system.

- 1) The AC schematic design representation for an AC power source is shown, in this example the AC power source is an electromagnetic generator. Each AC power source represents a single stator, with 2 coils.
- 2) The AC voltage generated by the motor cannot be used to charge everyday appliances, nor can it charge a 21700 battery power bank. Therefore, 2 full bridge rectifiers are used to convert the AC power to pulsating DC power, through the connection of 2 sets of 4 diodes in the configuration seen above.
- 3) A 470uF 100v supercapacitor is implemented to smooth pulsating DC voltage, to a stable direct current power source.
- 4) The voltage and current at this stage of this system does not meet the required power outputs that the power bank requires. Thus, a Buck boost converter is required, to turn the x voltage that the generator outputs, (x is a variable stemming from the RPM of the generator), into 16.8V that the 4S 21700 battery pack requires
- 5) The buck boost converter (outputting 16.8 volts) feeds into the positive and negative terminals of the BMS. The BMS, a circuit module that tracks the charging and discharging of individual batteries, protects the batteries against overheating, over discharging, and overcharging and prevents the degradation of the batteries.
- 6) The BMS is connected to the 4 21700 batteries in series.
- 7) The BMS and batteries feed into another buck boost module. This buck boost converter has an integrated voltage regulator and voltmeter, allowing the voltage to be monitored in real time as the power is modified for the desired application(s). For instance, say a radio requires a maximum of 12 volts, the power output from the battery pack can be stepped down from 16.8 volts (the output of the battery back), using the buck boost converter. Or for instance, if a refrigerator requires 30 volts, then the voltage can be stepped up from the original 16.8 volts. This module allows for adaptability in applications.

- 8) The buck boost converter feeds into 2 USB and 2 USB C PD ports, wired in parallel, so the voltage doesn't drop across the modules, instead the current drops. The following is not evident on the schematic, as on KICAD (the software used), a symbol for an output could not be found on the library.

Results

Motor/ prototype	Estimated peak voltage at 30 RPM (V)	Estimated voltage at 60 RPM (V)	Estimated voltage at 120 RPM (V)	Estimated voltage at 300 RPM (V)
Single phase axial flux- using 34 gauge wire (gen 5)	0.002	0.004	0.01	0.5
2 phase axial flux-using 30 gauge wire (gen 6)	0.004	0.008	0.5	3.2

To quantify the power generated by the system, a multimeter was used to test voltage (V), and a mark video system was used to quantify the speed of rotation (RPM). Testing voltage was a relatively straightforward process; the start and end wires of the 2 copper coils on each stator face were soldered in parallel so there would not be a voltage drop in the output voltage. The 4 output wires, 2 on either stator, were soldered to 2 full bridge rectifiers allowing the multimeter to measure the pulsating DC voltage output.

To measure the RPM of the rotor(s), a small white mark was painted onto one of the rotors. A video was then taken of the rotor spinning and was analyzed for how many times the white mark reached the 12 o'clock mark for a 60 second time span. Multiple trials had to be done to ensure the RPM was firstly an integer value, and secondly a multiple of 5.

Discussion

The lack of portable, affordable clean energy solutions on the market, has resulted in over 774 million people not having access to electricity as of 2022. The current results of this initiative indicate that a lightweight clean source of power has not yet been invented, as the peak voltage the generator was able to output was ~4 volts. One interpretation of these results is the lack of efficient coil windings, inadequate quantity of magnets, and insufficient rotational speed. In this context, wire coils that were meager in length led to a weaker magnetic field as each additional individual turn of copper wire results in an increase in induced magnetic field, and therefore an increased electric field.

Unfortunately, because a lighter weight and smaller overall footprint were the key objectives, fewer turns of wire were wound, and this led to a decrease in output voltage and current. Of course, copper coils in relation to any electromagnetic generator, can reach a tipping point, where too many coils are wound, and the resistance of the copper wire outweighs the total voltage generated, and the output wattage decreases in turn.

Following the construction of this project according to the preceding description of the system, the motor itself will be further iterated to produce more power and more efficiently. Furthermore, the integration of PD60W/100W modules for power delivery is being considered.

Aside from electronics, the mechanical system itself requires further development. While it is adjustable to any bike, it takes far too many resources, including material resources such as wrenches and screwdrivers, as well as time and energy to install the system on the bike.

Conclusion

The potential of this project knows no bounds. Clean, reliable, cheap electricity that can be sourced without the dependence on external factors is vital to levelling the global economic playing field and empowering populations in the global south, particularly on the continent of Africa (Stern et al., 2019). This paper examined the importance of electricity with the empowerment of populations across the global south. The proposed approach to mitigate this issue is harnessing the rotational mechanical energy potential of a bike wheel, using the spinning wheels and gears of a bike to spin an electromagnetic flywheel axial flux generator. While this system, with no doubt, requires further development and formal completion, not only does it build the basis of how we approach energy systems in the global south, but also how we view disenfranchised populations around the world, where opportunity and power is not a privilege of physical geography, but a basic human right shared by all. The path ahead is technical just as it is moral.

References

- AKIO TV. (2025, January 23). *Not the whole motor winding produces torque* [In an electric motor, not all copper is equally useful. Some parts of a winding are “inactive” and don’t contribute to producing torque. In this video, we take a closer look at this.]. *YouTube*. Retrieved 2025, from <https://www.youtube.com/watch?v=UZk0h8cnB7g>
- Aravind, B., & Khandelwal, B. (2020, January 8). *Towards the development of a high power density, high efficiency, micro power generator* [An innovative method to use combustion-based source for portable power generation for microelectromechanical systems with significant improvement in power density and conversion efficiency has been reported in this study. A triple microcombustor configurat]. *ScienceDirect*. Retrieved 2025, from <https://www.sciencedirect.com/science/article/abs/pii/S0306261919320732>
- Ardizzi, & Madison. (2018). *Bicycles for development in Uganda: A study of perceptions, organizations and globalization* [The bicycle has been hailed by the United Nations and various non-governmental organizations for its use in environmentally friendly forms of social and economic development (Yang & Wu, 2015). Despite these claims, there remains a lacuna of res]. *UBC Open Library*. Retrieved 2025, from <http://hdl.handle.net/2429/68183>
- Beepy, S. P., Torah, R. N., Tudor, M. J., Glynne-Jones, P., O'Donnell, T., Saha, T. R., & Roy, S. (2007, June 5). *A micro electromagnetic generator for vibration energy harvesting* [Vibration energy harvesting is receiving considerable interest as a means for powering wireless sensor nodes. This paper presents a small electromagnetic generator utilizing discrete components]. *IOP Science*. Retrieved 2025, from <https://iopscience.iop.org/article/10.1088/0960-1317/17/7/007/meta>
- DIY Perks. (2025, June 7). *Build your own portable power station (1200w, USB-C and more!)* [In this video we'll be building a super powerful battery station!]. *YouTube*. Retrieved 2025, from https://www.youtube.com/watch?v=adY-S8AH_Jc&t=464s
- Frey, D. (2024, June 10). *Bicycles can change lives, especially in rural Africa – new report looks at their use in Ghana and Malawi*. MIT D-Lab. <https://d-lab.mit.edu/news-blog/blog/bicycles-can-change-lives-especially-rural-africa-new-report-looks-their-use-ghana>
- Great Scott. (2020, August 30). *Does energy harvesting make any sense?! (Experiment)* [In this video I will be having a look at the subject of energy harvesting. I will explain where and when energy harvesting is being used and how we can create such systems ourselves]. *YouTube*. Retrieved 2025, from <https://www.youtube.com/watch?v=XUW21vWBdIw>
- Great Scott, & GreatScottLab. (2017, February 5). *Make your own Li-Ion battery pack* [In this project I will show you how to combine common 18650 Li-Ion batteries to create a battery pack that features a higher voltage, a bigger capacity, and useful safety measures]. *Instructables*. Retrieved 2025, from <https://www.instructables.com/Make-Your-Own-Li-Ion-Battery-Pack/>
- IEA. (2024). *Access to electricity – SDG7: Data and projections – Analysis*. International Energy Agency. Retrieved July 14, 2025, from <https://www.iea.org/reports/sdg7-data-and-projections/access-to-electricity>
- Ongaki, L., Maghanga, C. M., & Kerongo, O. (2021, June). *Map of Africa showing the rates of access to electricity and total populations without access to it (source: [3])*. *ResearchGate*. Retrieved 2025, from file:///Users/aarti/Downloads/Evaluation_of_the_Technical_Wind_Energy_Potential.pdf

- Ritchie, H., Rosado, P., & Roser, M. (2019, September). *Access to energy: Access to electricity and clean cooking fuels are vital for a good standard of living and good health. Our World in Data*. Retrieved 2025, from <https://ourworldindata.org/energy-access>
- Sardini, E., & Serpelloni, M. (2011, December). *An efficient electromagnetic power harvesting device for low-frequency applications* [Mechanical energy in the form of low-frequency vibrations can be advantageously converted to electrical energy using harvesting techniques]. *ScienceDirect*. Retrieved 2025, from <https://www.sciencedirect.com/science/article/abs/pii/S0924424711005279>
- Smith, R. M., & Thinking and Tinkering. (2022, May 4). *1530 - The hand crank generator - a big improvement. YouTube*. Retrieved 2025, from <https://www.youtube.com/watch?v=SsyPxKaHw7Q&t=70s>
- Stanton, T. (2021, September 27). *Super capacitor bike. YouTube*. Retrieved 2025, from https://www.youtube.com/watch?v=V_f8Q2_Q_J0
- Stanton, T. (2021, July 21). *Flywheel battery. YouTube*. Retrieved 2025, from <https://www.youtube.com/watch?v=yhu3s1ut3wM&t=338s>
- Stanton, T. (2024, December 7). *The most minimal electric bike. YouTube*. Retrieved 2025, from https://www.youtube.com/watch?v=aUPWfZS_uAM&t=428s
- Stanton, T. (2023, November 24). *Building a generator. YouTube*. Retrieved 2025, from <https://www.youtube.com/watch?v=tb3iN4m9Bik&t=243s>
- Stern, D. I, Burke, P. J, & Bruns, S. B. (2019). *The Impact of Electricity on Economic Development: A Macroeconomic Perspective*. UC Berkeley: Center for Effective Global Action. Retrieved 2025, from <https://escholarship.org/uc/item/7jb0015q>
- Westphal, M. I., Martin, S., & Satterthwaite, D. (2017, September 7). *Powering cities in the Global South: How energy access for all benefits the economy and the environment. World Resources Institute*. Retrieved 2025, from <https://www.wri.org/insights/powering-cities-global-south-how-energy-access-all-benefits-economy-and-environment>
- Wu, Z., Chu, Y., Cao, Z., Ding, R., Wang, S., & Ye, X. (2021, November). *An electrostatic-electromagnetic hybrid generator with largely enhanced energy conversion efficiency* [We propose an electrostatic-electromagnetic hybrid generator with enhanced efficiency for harvesting distributed mechanical energy]. *ScienceDirect*. Retrieved 2025, from <https://www.sciencedirect.com/science/article/abs/pii/S2211285521006807>
- Zhou, W., & Fong, M. (2025). *Novel flywheel alternator regenerative shock absorber outperforms others to boost EV & hybrid range* [EV/Hybrid vehicles help reduce earth's exponentially rising energy demand, yet their short mileage and GHG emissions reduce overall effectiveness]. *CWSF, 2025 Project Zone*. Retrieved 2025, from <https://partner.projectboard.world/ysc/project/novel-flywheel-alternator-regenerative-shock-absorber-outperforms-others-to-boost-ev-and-hybrid-rang>