Exposure to indoor air pollutants can increase the risk of memory loss: Advocating for improved indoor air quality

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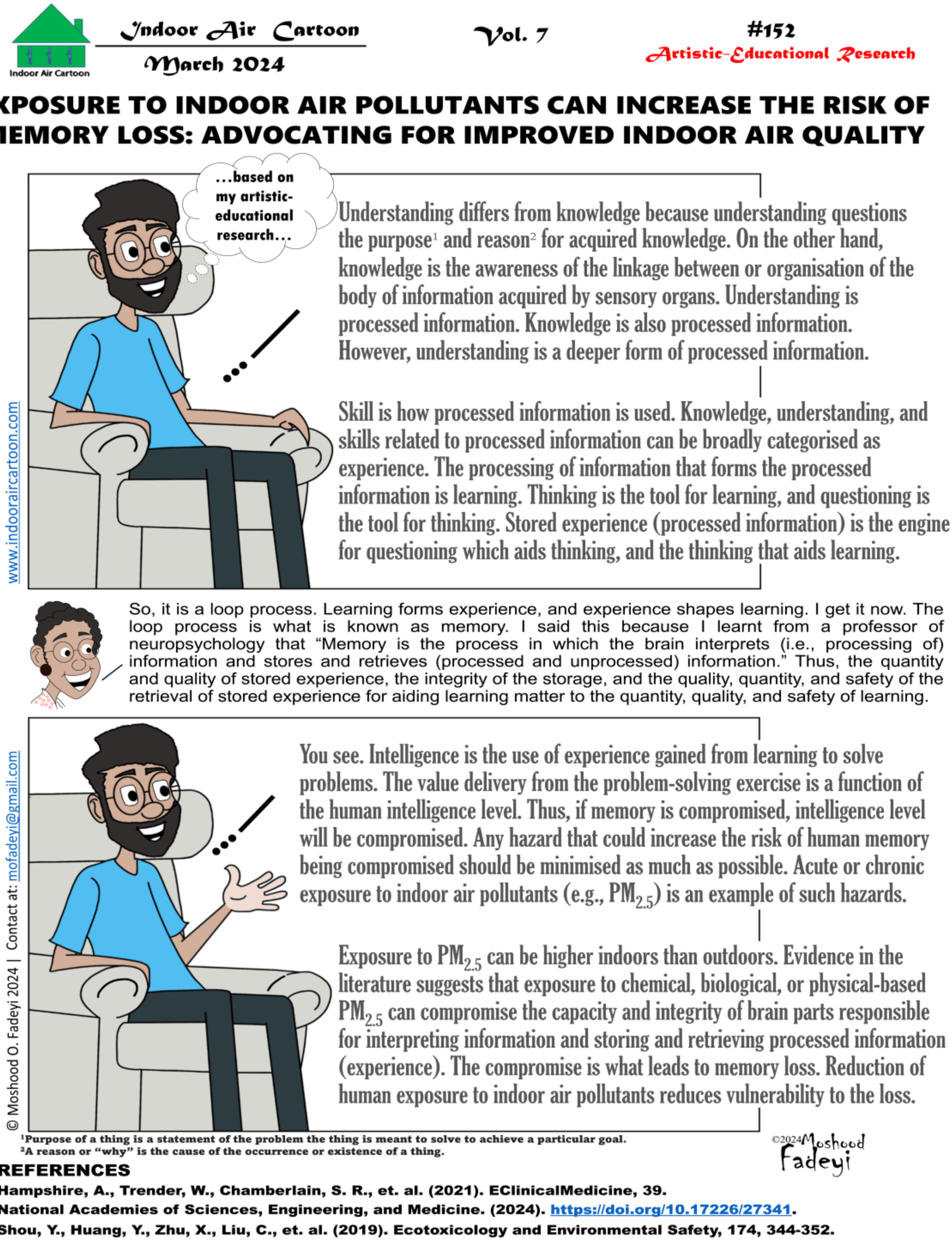

Fictional Case Story (Audio – available online) – Part 1

Fictional Case Story (Audio – available online) – Part 2

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Whether gradual or sudden, memory loss significantly affects learning and problem-solving abilities. Memory loss means the brain's ability to interpret or process information received from sense organs and store and retrieve unprocessed and processed information needed in the cognitive process has been compromised. Processed information is known as experience (i.e., knowledge, understanding, and skills). Even minor memory lapses can diminish the effectiveness of learning and problem-solving efforts, underscoring the critical importance of maintaining cognitive health for excellence in academic, professional, and personal pursuits. Unknown to many, exposure to air pollutants in indoor environments where humans spend most of their time can contribute to the risk of memory loss. The realisation of poor indoor air quality's potential impact on human memory and cognitive functioning resonated with a young man grappling with personal issues. Motivated to find answers, he embarked on research guided by the question: "How do ozone-initiated chemistry, ventilation rate, and filter efficiency impact the capability of the human brain to interpret information and store and retrieve unprocessed and processed information to aid learning and problem-solving involved in the cognitive processes?" In addition to his personal development, the man contributed significantly to academia, industry, and community to enhance educational, healthy living, and value delivery practices. The journey of the man, from his youth to later years, is the focus of this short fiction story.

1………………………………

Akanmu Abijah was a young and brilliant student who excelled in his studies. His excellence came as no surprise to those who interacted with him. Aside from his natural gift of easily remembering whatever he was taught or read, he was always very diligent and disciplined with his studies. However, from a tender age, Akanmu sought external validation like a compass seeks north. His quest for approval began innocently enough, but as he grew older, it morphed into an insatiable hunger, driving him to do anything to achieve external validation.

As a child, Akanmu craved his parents' praise. Whether he was acing a spelling bee or scoring a goal in football, he lived for their affirmations. Each accolade fed his young soul, reinforcing the belief that his worth was tied to the approval of others. During his elementary to high school days, Akanmu became his teachers' favourites.

Akanmu diligently completed his assignments and eagerly raised his hand in class with the primary purpose of seeking the admiration of his teachers and peers. He took great pleasure in the praises and admiration of his teachers, peers, and those who interacted with him in his academic journey as he equated external validation to self-worth.

As Akanmu progressed through high school, his relentless pursuit of external validation became increasingly consuming. Day by day, he chased after recognition like a parched wanderer in a desert. His grades were impeccable, and his extracurricular activities were numerous, yet a deep-seated insecurity lay beneath the facade of success. Akanmu yearned for validation like a plant thirsting for water, believing that acceptance from others held the key to his worth.

One fateful day, tragedy struck as he pushed himself to the brink in pursuit of yet another achievement. Engulfed in the whirlwind of competition and comparison, he neglected to care for himself, pushing his physical and mental limits beyond breaking point.

In the midst of a high-stakes high school certificate (HSC) examination, Akanmu collapsed, his body succumbing to the relentless pressure he had placed upon it. He put a lot of pressure on himself because he wanted to be the student with the best results in the HSC examination nationwide. He set the goal of being the best student nationwide for himself because he wanted to gain recognition and become a celebrity nationwide.

Rushed to the hospital, he found himself lying alone in a sterile room, surrounded by the cold machinery of medical intervention. The diagnosis was grim–severe exhaustion and burnout, a direct result of his relentless pursuit of external validation. As he lay there, weakened and vulnerable, Akanmu confronted the harsh reality of his choices. His single-minded focus on achievement had left him broken, his body and spirit shattered by the weight of his own expectations.

Despite the setback, Akanmu remained undeterred in his pursuit of external validation. Instead of recognising the toll it had taken on him, he doubled down on his efforts, determined to prove himself even more in the eyes of others. During his recovery, Akanmu immersed himself even deeper into his studies, determined to excel and gain the admiration of his peers and teachers once more. The tragedy only fueled his ambition, driving him to push himself harder than ever.

Inspired by his experience in the hospital, Akanmu set his sights on a career in chemical engineering, seeing it as yet another opportunity to prove his worth to the world. He saw the field as a prestigious path that would earn him the admiration and validation he craved. Despite the warnings of friends and family to slow down and prioritise his well-being, Akanmu remained steadfast in his pursuit of external validation. He was determined to achieve greatness at any cost, blind to the toll it was taking on his health and happiness.

Akanmu’s experience in the hospital opened his eyes to the critical role of chemical processes in healthcare. He chanced upon a magazine in the hospital’s library for recovering patients. After reading the magazine, he understood how pharmaceuticals, medical devices, and treatment methods relied on principles of chemistry and engineering to diagnose and treat illnesses effectively. Specifically, he learned the following.

Chemical engineers work to design and optimise processes for drug synthesis, ensuring the safe and efficient production of medications. They also contribute to the development of drug delivery systems, such as nanoparticles and micelles, which can improve the targeted delivery of drugs to specific tissues or cells in the body.

Additionally, chemical engineers produce medical devices and biomaterials used in healthcare. They work to develop materials with specific properties, such as biocompatibility and mechanical strength, for applications ranging from artificial organs to medical implants. By leveraging their materials science and engineering expertise, they contribute to advancements in regenerative medicine, tissue engineering, and personalised healthcare.

Furthermore, chemical engineering principles are applied to various diagnostic techniques and medical imaging technologies. Chemical engineers develop and optimise processes to produce contrast agents used in MRI, CT scans, and other imaging modalities, enhancing the visualisation of anatomical structures and pathological conditions.

For Akanmu, the intersection of chemical engineering and medicine presented a compelling opportunity to make a tangible impact on healthcare. He saw it as a field where his passion for science and engineering and his desire for external validation would blossom unprecedentedly.

By pursuing chemical engineering, he envisioned himself playing a vital role in developing innovative solutions to healthcare challenges, from drug delivery systems to medical devices, ultimately contributing to advancements in patient care and treatment outcomes and being seen as a saviour in society locally and internationally.

But to be honest, Akanmu was interested in pursuing chemical engineering for innovative development in the medical field because of how the chemical engineers reported in the magazine were celebrated worldwide as saviours in the 21st century.

Despite the challenges he faced, Akanmu achieved the aim he set for his HSC examination. He became the best student nationwide and the only student with a perfect HSC examination score. In the 102nd history of the examination, Akanmu was the fourth person to score a perfect score. He was admitted to study chemical engineering at the prestigious University of Vandemia in his country, Vandemia.

Akanmu also took an international university entrance examination that could give him access to universities in Hingland. He scored A* in all his subjects and was admitted to study chemical engineering at the University of Phonebridge, Hingland. The University of Phonebridge was one of the best universities in the world.

Akanmu was celebrated in his country for his academic achievement. The recognition and praise he received were far more than he expected. Additionally, the Federal Government of Vandemia gave him a prestigious overseas scholarship. The scholarship was very generous and non-bonded.

Akanmu's stellar academic record and passionate pursuit of knowledge impressed the admissions committee, earning him a coveted spot among the brightest minds in the chemical engineering department at the University of Phonebridge. Despite his achievements and external validation he got, Akanmu did not feel the sense of worth and satisfaction he craved from the external validation he sought.

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Once enrolled at the University of Phonebridge, Akanmu threw himself into his studies with unparalleled dedication and fervour in the hope of gaining external validation. He devoured textbooks and assisted in groundbreaking research conducted by esteemed professors and researchers at the university. His relentless work ethic and insatiable thirst for knowledge propelled him to the top of his class, earning him accolades and admiration from faculty and peers.

Yet, beneath the facade of success, Akanmu's pursuit of external validation continued unabated. Despite his academic triumphs, he remained plagued by self-doubt and insecurity, seeking validation from others to fill the void within. However, Akanmu's journey took a dark turn when an unforeseen incident shattered his carefully constructed facade of success. A malicious rumour spread throughout the university, tarnishing Akanmu's reputation and casting doubt on his achievements.

The rumour was started by a group of students from the chemical engineering department who were Hingland citizens. This group of envious students started a rumour laden with spite and resentment. They spoke of Akanmu, weaving a web of deceit and distortion, fuelled by their own insecurities and fears of inadequacy.

This group of students felt insecure about Akanmu's achievements and brilliance. At the end of the first semester of year 3 of a 4-year bachelor's degree programme, Akanmu's CGPA (Cumulative Grade Point Average) was still 5.0 out of 5.0. No matter how hard the students who were brilliant in their own right with CGPA in the first-class division tried, they felt they could not match up to Akanmu's brilliance. Furthermore, they could not believe that a student from a developing country like Vandemia could be so brilliant. They never believed that somebody from such a country could even be more brilliant than them.

The rumour they concocted was as insidious as it was false, a venomous tale designed to tarnish Akanmu's reputation. The whispers grew louder, spreading like wildfire through the corridors of academia. They spoke of unethical behaviour, academic misconduct, and deceitful practices allegedly perpetrated by Akanmu.

Tales of fabricated events, plagiarised work, falsified results of laboratory work assignments, and cheating during tests and examinations circulated, staining the impeccable reputation of the unsuspecting Akanmu. As the rumour gained momentum, its tendrils reached far and wide, infiltrating the ears of professors and fellow students alike. Doubt crept in, casting shadows of suspicion upon Akanmu.

For Akanmu, the impact was devastating. What had once been a sanctuary of intellectual pursuit now felt like a battleground, where every glance carried a hidden accusation, and every conversation dripped with scepticism. The weight of the false allegations bore down upon Akanmu, threatening to crush his spirit and shatter his confidence.

Despite his innocence, Akanmu was thrust into a maelstrom of doubt and distrust, his once-promising future hanging in the balance. The malicious rumour, born of jealousy and insecurity, had taken root, its poisonous tendrils threatening to destroy his reputation, mental health, and well-being.

As the malicious rumours swelled around him, Akanmu felt the weight of the accusations bearing down on him. Every interaction, every glance, seemed to carry a shadow of doubt, leaving him feeling isolated and vulnerable. For someone who had always sought external admiration and validation, the onslaught of suspicion and distrust was particularly devastating.

At first, Akanmu desperately tried to prove his innocence, seeking validation from those around him. He poured over his assignment reports, meticulously examining every detail in a bid to refute the allegations against him. He sought out his colleagues and professors, pleading his case, hoping to find support and understanding.

However, as the days turned into weeks and the whispers persisted, Akanmu began to realise the futility of his efforts. The doubts remained no matter how much evidence he presented or how passionately he defended himself. It was a bitter pill to swallow, but Akanmu slowly accepted that he could not control what others thought of him.

In the depths of despair, Akanmu sought the help of the university counselling services department. Akanmu had several sessions with a counsellor in the university counselling services department. The situation reached a critical point when the head of the university counselling services department, upon noticing the toll the rumours were taking on Akanmu's mental health and well-being, decided to escalate the issue to higher authorities.

Upon receiving the report from the head of the counselling services department, the Dean of the engineering faculty took swift action. Recognising the gravity of the situation and the potential harm it could cause to Akanmu's academic and personal life, the Dean convened a meeting with key stakeholders, including faculty members, administrators, and counselling professionals.

During the meeting, the Dean emphasised the importance of upholding integrity and fairness within the academic community and expressed concern over the unsubstantiated rumours circulating about Akanmu. The provost, being informed of the situation, supported the Dean's actions and pledged to provide any necessary resources to address the issue promptly.

As a result of this intervention, the university took proactive steps to counteract the rumours and support Akanmu. The Dean issued a statement to all faculty and students, reaffirming the university's commitment to fostering a respectful and inclusive environment. Additionally, counselling services were made readily available to Akanmu and any other students experiencing similar challenges.

With the backing of the university administration, the rumours gradually lost their potency as the truth prevailed, and Akanmu was able to continue his academic pursuits without the shadow of suspicion looming over him.

After completing his counselling sessions, Akanmu reflected on his values and priorities. He realised that his relentless pursuit of external validation had left him vulnerable to the whims of others and that true confidence could only come from within. His mental health was particularly affected significantly because he was a person whose sense of worth depended entirely on what others thought or said about him.

Akanmu began to focus inward, seeking solace in his own sense of self-worth rather than the opinions of others. As he withdrew from the relentless cycle of seeking approval, he discovered a newfound sense of liberation. He no longer felt the need to prove himself constantly or seek validation from others. Instead, he channeled his energy into his work, finding satisfaction in the pursuit of knowledge for its own sake.

After introspection and self-reflection on the transformative power of internal validation, prompted by the unpleasant situation he experienced, Akanmu found himself at a crossroads when deciding on the topic for his undergraduate studies. Initially, he was swayed by the allure of pursuing a popular topic in academia, industry, and the community, solely driven by the desire for external validation, even though he did not feel a genuine connection with the topic.

However, as he delved deeper into his own motivations and aspirations, he realised the futility of seeking validation from external sources. He understood that true fulfilment and satisfaction could only come from pursuing something he was genuinely passionate about rather than chasing recognition from others.

With this newfound clarity, Akanmu boldly decided to veer away from the conventional path and instead focus on a topic that resonated with his interests and values. Akanmu remembered that a module relating to indoor air quality and health gave him a fulfilment level he had never experienced before.

Akanmu felt so connected to the topics addressed in the module. Even though indoor air quality was not a subject matter that enjoyed widespread popularity in the industry and community, Akanmu chose to pursue it for several compelling reasons.

Firstly, Akanmu recognised the intrinsic importance of indoor air quality and health in shaping the well-being of individuals and communities. He saw it as a pressing issue with far-reaching implications for public health, particularly in urban environments where people spend most of their time indoors. By addressing indoor air quality and health, Akanmu believed he could make a meaningful impact on improving people’s lives and fostering healthier environments for all.

Secondly, Akanmu was drawn to the interdisciplinary nature of indoor air quality and health research and practice. He saw it as an opportunity to integrate principles from various fields, including engineering, environmental science, and public health, to tackle complex challenges and develop innovative solutions. This interdisciplinary approach appealed to Akanmu’s curiosity and passion for holistic problem-solving, providing him with a rich and rewarding academic experience.

Additionally, Akanmu saw indoor air quality as a burgeoning area of research with ample opportunities for exploration and advancement, where he could contribute his own unique insights and ideas to the collective body of knowledge. By pushing the boundaries of understanding in this field, Akanmu hoped to pave the way for new technologies and strategies that would improve indoor environments and promote human health.

Moreover, Akanmu recognised the personal significance of pursuing a topic that aligned with his values and interests rather than seeking external validation from others. He understood that true fulfilment could only come from following his passion and staying true to himself, regardless of outside opinions or expectations.

For his undergraduate dissertation, Akanmu chose to investigate the effects of indoor air pollutants on respiratory health outcomes in urban environments. He conducted a comprehensive review of existing literature, analysed air quality data from various indoor settings, and surveyed individuals to assess their exposure to indoor pollutants.

Through his research, Akanmu made several key findings. He discovered a concerning correlation between high levels of indoor air pollutants, such as volatile organic compounds (VOCs) and particulate matter, and increased incidence of respiratory issues among urban dwellers. His analysis also revealed disparities in exposure levels based on factors such as socioeconomic status and housing conditions, highlighting the need for targeted interventions to address environmental justice concerns.

However, as Akanmu delved deeper into his undergraduate research studies, he stumbled upon a significant gap in knowledge: the potential impact of indoor air pollutants on cognitive health, particularly memory loss. While existing research had primarily focused on respiratory and other health problems, little attention had been paid to the neurological effects of indoor air pollution.

Akanmu became conscious of the potential impact of indoor air pollutants on human memory loss after listening to news about the prevalent cases of memory loss among people living and working in buildings near major roads and factories, which is considerably more than among people who do not live in buildings with such proximity. The news was based on case studies conducted by Hingland's Ministry of Health.

The case studies did not link the observation to indoor air quality conditions. However, Akanmu knew from his undergraduate research studies on indoor air quality that most exposure to air pollutants from outdoor sources occurs in indoor environments. So, he quickly searched the literature database to see if there was evidence in the literature linking exposure to indoor air pollutants to memory loss.

Akanmu searched and searched, but he could not find a definite link. Akanmu did this even when the impact of poor indoor air quality on memory loss was not part of her undergraduate studies. Akanmu consulted his supervisor, who told him in her 34 years of conducting indoor air quality research, she was not aware of research works in such an area.

The realisation that little attention had been paid to the neurological effects of indoor air pollution struck a profound chord with Akanmu. It was not just a simple acknowledgment of a gap in knowledge; rather, it ignited a spark within him, stirring a deep sense of curiosity and urgency to explore this overlooked area of research.

As Akanmu delved deeper into the existing literature, he could not shake off the significance of this gap in knowledge. He began to connect the dots between his findings on respiratory health outcomes and the broader implications for cognitive function. The more he pondered the potential impact of indoor air pollutants on memory loss, the more he realised the gravity of the situation.

Akanmu could not help but envision the countless individuals unknowingly exposed to harmful indoor pollutants, their cognitive health potentially compromised without them even realising it. He saw the profound implications of this for public health, particularly in densely populated urban areas where indoor air quality often falls below acceptable standards.

Furthermore, Akanmu's personal experiences and observations added fuel to his determination. He recalled instances of family members and friends experiencing unexplained cognitive decline, wondering if indoor air pollution could be a contributing factor. These real-world connections made the issue feel all the more pressing and personal to him, driving home the importance of addressing this gap in knowledge.

As Akanmu reflected on the implications of his undergraduate dissertation, he realised that he could not simply ignore this newfound insight. He felt a moral obligation to shed light on the potential link between indoor air pollutants and memory loss, knowing that his research could have far-reaching implications for public health policy and intervention strategies.

This realisation sparked a profound shift in Akanmu's research focus, prompting him to reconsider the scope of his work and the broader implications of his findings. It was no longer just about academic curiosity; it was about making a tangible difference in the lives of countless individuals affected by indoor air pollution.

Motivated by this newfound sense of purpose and urgency, Akanmu boldly decided to pursue a PhD focused on exploring the neurological effects of indoor air pollutants. He saw it as an opportunity to fill a critical gap in knowledge, advocate for greater awareness and action on indoor air quality issues, and, ultimately, improve the lives of individuals affected by cognitive decline due to poor indoor air quality.

Akanmu's undergraduate dissertation was judged the best undergraduate dissertation. He maintained and graduated with an unprecedented perfect CGPA (5.0 out of 5.0), a feat that had never been achieved in the prestigious university's chemical engineering department's 63-year history.

His professors marvelled at his intellect and dedication, recognising him as a prodigious talent destined for greatness. Akanmu was awarded a scholarship to pursue a PhD in the same department and under the same supervisor, an indoor air quality expert, who supervised his undergraduate dissertation.

Akanmu started his PhD studies a few months after graduating from his undergraduate degree programme. His PhD research was guided by a main research question that informed Akanmu's PhD research studies.

The main research question of Akanmu's PhD thesis is: "How do ozone-initiated chemistry, ventilation rate, and filter efficiency impact the capability of the human brain to interpret information and store and retrieve unprocessed information and processed information to aid learning and problem-solving involved in the cognitive processes?" Provided below are key summaries of the research methodologies and findings Akanmu reported in his PhD studies.

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Research Methodology: The experiment conducted to address this research objective involved dividing subjects into two groups: an experimental group exposed to ozone-initiated chemistry and a control group not exposed to such conditions. Both groups are carefully matched in terms of demographic factors to ensure the study's validity. Ethical approval was attained to conduct the study.

In the exposed group, ozone and limonene were injected into the field environmental chamber via the supply air duct to achieve steady stated ozone and limonene concentrations at non-dangerous levels and within regulatory standards.

Ozone is known as a powerful oxidising agent that is harmful to humans. It was also reported in the literature that the products of ozone-initiated chemistry can be more harmful than ozone itself. The concentration of secondary organic aerosols (i.e., particulate matter) generated from the ozone-limonene chemistry was also monitored. The exposure period lasted for 6 hours.

In the control group, there was no injection of ozone and limonene, or any other air pollutants in the field environmental chamber they occupied. The control group remains in a similar environment without exposure. The only difference between the exposed and control groups was the injection of ozone and limonene.

The separate supply air duct serving each of the field environmental chambers is designed to have the capacity to supply air with a mixture of ventilation and recirculated air. To reduce the impact of outdoor air pollutants, particularly ozone and organic compounds, on the indoor air in the two field environmental chambers, an activated carbon filter was placed at the fresh outdoor air intake of the separate air handling unit serving each of the field environmental chambers used for the experimental studies.

The experiments were conducted at nine different ventilation and filter efficiency conditions for both exposed and control groups. The ventilation conditions were "no ventilation", "low ventilation rate", and "high ventilation rate" conditions. The filter conditions were "no filter", "low efficiency filter", and "high efficiency filter".

The experimental matrix led to nine experimental conditions at constant ozone and limonene injection including (i) no ventilation and no filter, (ii) no ventilation and low efficiency filter, (iii) no ventilation and high efficiency filter, (iv) low ventilation rate and no filters, (v) low ventilation rate and low efficiency filter, (vi) low ventilation rate and high efficiency filter, (vii) high ventilation rate and no filter, (viii) high ventilation rate and low efficiency filter, (ix) high ventilation rate and high efficiency filter.

To assess the impact of exposure on neural mechanisms, various neuroimaging and neurophysiological techniques were employed for subjects in the exposure and control groups. Functional magnetic resonance imaging (fMRI) was utilised to observe changes in brain activity before and after exposure. Additionally, neurotransmitter levels in the brain were measured using techniques such as microdialysis.

Neurotransmitter levels were measured to provide insights into the mechanisms underlying normal brain function. Synaptic plasticity is assessed through electrophysiological recordings to examine changes in synaptic markers. Synaptic plasticity is critical in various cognitive functions, including learning, memory, and adaptation to new experiences.

Ethical guidelines for human research were strictly adhered to throughout the study. Informed consent was obtained from all participants, and measures were taken to ensure subjects' safety during exposure. Risks associated with exposure to ozone-initiated chemistry were minimised, and participants were fully informed about the nature of the study.

Data analysis involved quantifying neuroimaging findings, neurotransmitter levels, synaptic plasticity markers, and measured concentrations of ozone, limonene, and $PM_{2.5}$ as an indication of the generated SOAs. T-tests were employed to compare data between the experimental and control groups, filter conditions, and ventilation conditions. Correlation analysis was conducted to examine the relationship between measured air pollutants and the neural changes, neurotransmitter levels, and synaptic plasticity markers.

Subjects underwent cognitive testing before and after the 6-hour exposure period to assess baseline cognitive functioning and measure any changes or impairments in cognitive abilities resulting from exposure to ozone, limonene, and ozone-initiated chemistry products. This was done to compare cognitive performance across all domains before and after exposure and evaluate the immediate effects of exposure on cognitive functioning.

The same cognitive test was administered to subjects in the control group before and after 6 hours of staying in a filtered environmental chamber with no injections. Subjects in the exposed and control groups underwent the cognitive assessment in the same room, an examination hall of the university in the same building housing the two chambers used for the experimental studies.

There were no injections in the examination hall. The air handling unit serving the examination hall was different from the air handling unit that served each of the two field environmental chambers used for the experimental studies.

Standardised neuropsychological tests, known as the Montreal Cognitive Assessment (MoCA), were administered to evaluate cognitive abilities across all domains, including the brain's ability to interpret received information from sense organs and store and retrieve the stored processed information to support learning, decision-making, and problem-solving.

Subjects' capacity to acquire and retain newly processed information over time was evaluated using a standardised learning paradigm, the Rey Auditory Verbal Learning Test (RAVLT). Assessments were designed to measure subjects' ability to acquire and retain new information over time. Performance metrics used were accuracy rates, retention rates, and reaction times.

Subjects' problem-solving skills were assessed through standardised tasks involving logical reasoning, planning, and decision-making. Subjects completed problem-solving tasks, specifically the Wisconsin Card Sorting Test (WCST), to assess executive function. Problem-solving performances were evaluated based on accuracy, efficiency, and strategy utilisation.

Subjects in the exposure group were exposed to ozone, limonene, and ozone-limonene chemistry products for 6 hours in a field environmental chamber. Subjects in the control group did not undergo any exposure.

Following exposure, the same neuropsychological tests used in the pre-exposure assessment were re-administered to measure changes in cognitive, learning, and problem-solving performances. Learning and problem-solving performance between the exposure and control groups were compared to assess the impact of exposure on cognitive abilities. The comparison is essential to (i) isolate the effect of exposure, (ii) assess differential effects, and (iii) enhance the interpretation of findings.

Isolating the effect of exposure is essential because while cognitive abilities, including learning and problem-solving abilities, are distinct constructs, they are interconnected. Exposure to air pollutants like ozone, limonene, and ozone-initiated chemistry products may affect cognitive abilities.

Assessing differential effects is essential because different subjects may respond differently to exposure based on factors such as susceptibility, resilience, and genetic predisposition. Comparing learning and problem-solving performances between the exposure and control groups enables the assessment of whether the impact of exposure varies across different cognitive domains. Comparison helps in enhancing the interpretation of findings because it helps to draw more robust conclusions about the causal relationship between exposure to ozone-initiated chemistry and changes in cognitive abilities.

T-tests were used in the data analysis to compare cognitive performance between groups. Potential correlations between specific cognitive impairments (e.g., memory deficits) and performance on learning and problem-solving tasks were investigated. Additional analyses were explored to assess the moderating effects of demographic variables or severity of cognitive impairment on cognitive performance.

An AI-based simulation tool was designed to model neural networks and their responses to diverse stimuli. This simulation environment emulates a simplified version of the brain, encompassing essential regions involved in information processing, synaptic connections, and neurotransmitter release sites. By utilising this advanced technology, the intricate interplay between environmental stressors and neural dynamics in a controlled yet realistic setting was investigated.

Key variables such as ozone and limonene injection rates, indoor air chemistry phenomena forming SOAs, ventilation and filter conditions, and exposure durations were meticulously determined. Establishing baseline conditions for neural activity and neurotransmitter levels within the simulated brain was a foundation for subsequent analyses, ensuring consistency and comparability across different experimental scenarios.

Simulation scenarios encompass a spectrum of injection rates, which translated to “low”, “medium”, “high”, “very high”, and “dangerously high” ozone and limonene exposure at steady state. The simulated “low” steady-state concentration is the same as that of real-life experimental studies. The “medium” represents a concentration slightly above the regulatory standards. The “dangerously high” ozone steady-state concentration was realistic in countries where outdoor air is highly populated with ozone. The “dangerously high” limonene concentration was a realistic concentration in countries where the use of perfume or other sources of cyclic terpene hydrocarbon is prevalent.

The diversity in injection scenarios enabled a comprehensive assessment of the dose-dependent effects of pollutant exposure on neural mechanisms, elucidating potential toxicity thresholds and underlying mechanisms of action.

Sophisticated algorithms within the simulation tool were employed to model human neural responses to ozone-limonene exposure. The algorithms aided in the simulation of changes in synaptic plasticity and neurotransmitter activity, unraveling the complex cascade of events triggered by ozone, limonene, and ozone-initiated chemistry products, which include SOAs, within the neural milieu.

Simulation results were validated by comparing them to experimental data from the field environmental chambers. Iterative calibration of simulation parameters ensured the accuracy and reliability of the simulated responses, aligning them with known physiological responses to air pollutants.

Simulated neural responses were visualised using graphical representations to facilitate intuitive comprehension and elucidation of underlying mechanisms. The graphical representations offered insights into changes in synaptic plasticity and neurotransmitter activity across different exposure conditions in the exposed group and the non-exposure condition in the controlled group, contributing to a nuanced understanding of pollutant-induced neurobiological alterations.

The AI-based simulation was also used to simulate subjects performing the Montreal Cognitive Assessment (MoCA), Rey Auditory Verbal Learning Test (RAVLT), and the Wisconsin Card Sorting Test (WCST) in the exposed and control groups before and after the simulated 6-hour experiment in a field environmental chamber.

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Research Findings: The findings from functional magnetic resonance imaging (fMRI) analysis, along with measurements of neurotransmitter levels and synaptic markers, provide valuable insights into how exposure to ozone and its initiated chemistry products can lead to abnormal activities in the brain, potentially compromising its abilities to interpret received information from sense organs and store and retrieve unprocessed and processed information for further learning or problem-solving.

There was a significant difference in brain activity patterns before and after exposure to ozone, limonene, and ozone-limonene-initiated chemistry products for subjects in the exposed group. Although the difference was significant, the brain activity patterns after exposure were still within a healthy range.

These differences manifested as changes in the activation levels and spatial distribution of brain regions involved in interpreting sensory perception, cognitive processing, and higher-order cognitive functions. The observed hyperactivity and hypoactivity in sensory processing regions, measured with the aid of the fMRI, suggest an increase in the risk of disruptions in interpreting sensory information provided to the brain by the sense organs.

The observed abnormal activity patterns in higher-order brain regions responsible for cognitive functions suggest an increased risk of impaired storage and retrieval of unprocessed and processed information, potentially increasing the risk of compromised memory formation, attentional control, and decision-making abilities.

The observed alterations in brain activity patterns before and after exposure within the exposed group indicate how exposure to the studied air pollutants can cause disruptions in neural processing even within a short period – 6 hours. The observations suggest the risk may worsen to a dangerous level if exposure to ozone and its initiated chemistry products is acute or chronic.

The measured neurotransmitter levels and synaptic markers provide additional insights into the underlying neurobiological mechanisms contributing to changes in brain activity patterns. Alterations in neurotransmitter levels, such as dopamine, serotonin, and glutamate, which are of interest in the study, influenced synaptic transmission and neural excitability, modulating brain activity patterns.

Changes in synaptic markers, indicative of synaptic plasticity and neuronal connectivity, reflect structural and functional alterations in neural circuits following exposure to the studied air pollutants, further contributing to abnormal brain activity patterns.

As expected, there were no noticeable changes in the brain activity patterns of subjects in the control group who were not exposed to ozone, limonene, and the initiated chemistry products. Thus, the strength of the difference in brain activity patterns between before and after exposure is similar to the strength of the difference between subjects in the exposed group and the control group.

Ventilation and filter conditions were found to influence the observed brain activity patterns. The difference between the change in brain activity patterns observed in the exposed group and that of the change observed in subjects in the control group after the 6-hour experiment was significant for experimental conditions when no ventilation was supplied to the field environmental chambers. These experimental conditions include (i) no ventilation and no filter, (ii) no ventilation and low-efficiency filter, (iii) no ventilation and high-efficiency filter, and (iv) low ventilation rate and no filters.

A subtle difference was observed for the experimental condition involving a higher ventilation rate and a high-efficiency filter. A modest difference was observed for other experimental conditions, which include (i) low ventilation rate and low-efficiency filter, (ii) low ventilation rate and high-efficiency filter, (iii) high ventilation rate and no filter, and (iv) high ventilation rate and low-efficiency filter.

Correlation analyses indicated associations between the neurotransmitter levels, synaptic markers, and concentrations of ozone, limonene, and the initiated chemistry products, i.e., secondary organic aerosols (SOAs). The observations suggest a potentially higher risk for building occupants worldwide experiencing acute or chronic exposure due to a polluted outdoor environment.

Both the exposed and control groups showed similar baseline cognitive functioning before exposure, as measured by the Montreal Cognitive Assessment (MoCA). There was no difference in cognitive abilities across all domains between the two groups before exposure.

Following exposure, subjects in the exposed group demonstrated a decreased capacity to acquire and retain new unprocessed and processed information over time compared to the control group with no noticeable difference, as assessed by Rey Auditory Verbal Learning Test (RAVLT) scores.

Subjects in the exposed group exhibited a decline in problem-solving skills compared to the control group, with no noticeable decline, as assessed by the Wisconsin Card Sorting Test (WCST). Subjects exposed to the studied air pollutants showed lower levels of accuracy and efficiency in completing the tasks and lower strategy utilisation compared to those in the control group. Overall, there was evidence to suggest an impact of exposure to ozone, limonene, and ozone-limonene chemistry products on cognitive abilities across all domains, including learning and problem-solving skills.

The observed effects of exposure to air pollutants in the exposed group were significantly higher due to the absence of ventilation and filtration, leading to a significant decline in cognitive abilities across all studied domains (learning and problem-solving) of subjects in the exposed group compared to subjects in the control group.

Similar to the condition with no ventilation and no filter, subjects exposed to the studied air pollutants with no ventilation and low-efficiency filter conditions exhibited significant declines in cognitive abilities across all domains compared to subjects in the control group.

Despite the presence of a high-efficiency filter, subjects exposed to the studied air pollutants with no ventilation conditions still experienced a decline in cognitive abilities across all domains studied compared to subjects in the control group, although the effect was less compared to conditions without filtration, but still a significant difference.

Subjects exposed to the studied air pollutants with low ventilation rates and no filters showed moderate declines in cognitive abilities across all domains studied compared to subjects in the control group. While cognitive impairments were observed, they were less pronounced compared to conditions with no ventilation.

Similar to the condition with low ventilation rates and no filters, subjects exposed to the studied air pollutants with low ventilation rates and low-efficiency filter conditions exhibited moderate declines in cognitive abilities across all domains compared to subjects in the control group.

Subjects exposed to the studied air pollutants with low ventilation rates and high-efficiency filter conditions showed modest declines in cognitive abilities across all domains compared to subjects in the control group.

Subjects exposed to the studied air pollutants with high ventilation rates and no filters demonstrated minimal declines in cognitive abilities across all domains compared to subjects in the control group.

Subjects exposed to the studied air pollutants with high ventilation rates and low-efficiency filter conditions exhibited minor declines in cognitive abilities across all domains compared to subjects in the control group. While cognitive impairments were observed, they were lesser compared to conditions with low ventilation rates or filtration efficiency.

Subjects exposed to the studied air pollutants with higher ventilation rates and high-efficiency filter conditions showed preserved cognitive abilities across all domains compared to subjects in the control group, indicating a minimal impact of exposure under conditions of optimal ventilation and filtration.

The experimental findings should be viewed in the context that in the exposed group, ozone and limonene were injected to ensure the steady-state concentrations of the reactants, ozone and limonene, were within regulatory standards and non-dangerous levels.

As evident in the simulation studies, the higher the concentrations of air pollutants subjects in the exposed group were exposed to, the higher the strength of the observed differences for comparison between the exposure group and the control group and before and after exposure for the exposed group.

The impact of the injection rates leading to moderate to dangerously high steady-state concentrations of the reactants on exposed group subjects' brain activity patterns influencing memory levels and cognitive abilities before and after exposure were significant for all ventilation and filter conditions.

The differences between exposed group subjects and control group subjects were also significant for all ventilation and filter conditions. However, the effect of increasing the ventilation rate and filter efficiency in reducing the impact was evident, suggesting the importance of adequate ventilation rate and filter efficiency for healthy indoor air.

In conclusion, exposure to ozone-initiated chemistry without adequate ventilation and filtration significantly impairs cognitive processes across multiple domains due to impairment to subjects' memory.

Subjects exposed to ozone-initiated chemistry exhibited notable deficits in their abilities to interpret information received from sense organs and store and retrieve unprocessed and processed information for further learning or problem-solving. These findings underscore the detrimental impact of indoor air pollutants on human memory and the impact of deficiency in human memory on cognitive functioning.

Ventilation rate emerged as a critical factor in mitigating the adverse effects of ozone-initiated chemistry on human cognitive processes. Higher ventilation rates were associated with better cognitive outcomes, suggesting that adequate ventilation helps to reduce the concentration of indoor air pollutants and preserve cognitive functioning.

The efficiency of air filtration systems played a crucial role in protecting cognitive processes from the effects of ozone-initiated chemistry. High-efficiency filters were effective in removing pollutants from indoor air, thereby preserving cognitive abilities. In contrast, low-efficiency filters provided limited protection against cognitive impairment.

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Finally, after years of hard work and dedication, Akanmu successfully defended his PhD thesis, presenting groundbreaking findings that shed new light on the impact of indoor air pollutants on cognitive processes. His research garnered widespread acclaim within the academic community, earning him accolades and recognition from his peers.

However, for Akanmu, the true reward lay not in the external accolades but in the satisfaction of knowing that his work had the potential to make a meaningful difference in people's lives. Armed with his newfound knowledge and expertise, he, with the support of his supervisor, set out to share his findings with the world, determined to make a positive impact on society.

As word of Akanmu's groundbreaking research spread, job opportunities began to pour in from prestigious universities and research institutions around the globe. Recognising his expertise and contributions to the field, they sought to recruit him as a professor and researcher, offering him positions of leadership and influence.

However, despite the allure of these tempting offers, Akanmu remained grounded in his values and principles. Instead of being swayed by external validation or the allure of fame and fortune, he focused on his internal compass, guided by his passion for research and his desire to make a difference in human lives.

In the end, Akanmu chose a position at a renowned university, the University of Lambaba, Hingland, where he continued his research and mentored the next generation of aspiring scientists. As a professor, he found fulfilment in sharing his knowledge and inspiring others to pursue their passions, knowing that true success came not from external accolades, but from the peace of mind that comes from staying true to oneself.

As Akanmu delved deeper into his research on the effects of indoor air quality on human memory and cognitive functioning, he could not help but notice a glaring gap in scientific literature and practice in the industry. Despite the wealth of knowledge and data available, there was a significant disconnect between the information presented in peer-reviewed scientific research publications and its accessibility to non-experts or non-scientific-oriented readers.

Even his PhD research efforts, which were well accepted and celebrated in academia and he thought would impact the industry and the community as he researched prevalent problems in society, did not have much impact.

People in the industry and community do not have access to all the papers he published in top-tier peer-reviewed journals and conferences. The language in which his papers, similar to other scientific papers, made it difficult for industry professionals and people in the industry to relate to the message in his papers.

Reflecting on this observation, Akanmu realised that the lack of simplified, contextualised, and relatable information on indoor air quality and health, as well as sustainable building engineering, was impeding critical thinking and problem-solving in both the industry and daily life activities.

Akanmu believed that the complex language and technical jargon used in scientific research publications made it difficult for laypeople to grasp the importance and relevance of the findings, hindering their ability to make informed decisions about their indoor environments.

Driven by his belief in the power of interdisciplinary communication and creative expression, Akanmu boldly decided to shift his focus from traditional scientific research to artistic-educational research.

Akanmu recognised the need for a communication solution that bridged engineering, science, art, and literature–a platform that encouraged questioning and fostered a deeper understanding of complex concepts related to indoor air quality and health and value delivery in sustainable building engineering.

The decision to make the switch was easier for Akanmu as he genuinely does not seek external validation, and solving human problems was the main driver that gave him satisfaction and a sense of worth.

Despite facing scepticism and resistance from his peers in the academic community, Akanmu remained steadfast in his conviction that creative expression and interdisciplinary communication were essential for driving meaningful change.

Akanmu persevered in his efforts to develop educational resources that empowered people to think critically about indoor air quality and health and value delivery in sustainable building engineering, inspiring them to take action to create healthier and more sustainable indoor environments.

Drawing on his background and understanding of the impact of indoor air quality on human memory and cognitive functioning and his passion for the arts, Akanmu embarked on a journey to develop innovative educational materials that simplified and contextualised information about indoor air quality and health and value delivery in sustainable building engineering. Through a combination of visual arts and storytelling, he sought to engage audiences in a way that transcended traditional scientific discourse and sparked curiosity and reflection.

Akanmu's approach to research was deeply rooted in his philosophy of art. Akanmu believed that art is a work designed or created to depict hypothetical or real-life scenarios that influence humans' questioning, thinking, learning, and use of experience (knowledge, understanding, and skills) to solve problems.

Akanmu believed that hypothetical scenarios could be powerful tools for driving change and improving outcomes in indoor air quality and health and value delivery in sustainable building engineering. He focused on developing simplified, contextualised, and relatable scenarios; he set out to bridge the gap between scientific research and practical application, aiming to empower students, industry professionals, and communities for healthy living and practices.

One of Akanmu's key initiatives involved creating hypothetical scenarios that challenged individuals to think critically and problem-solve in real-world settings. For example, he developed a case study that presented a hypothetical situation where a school building experienced poor indoor air quality due to inadequate ventilation and filtration systems.

By analysing this scenario, students were encouraged to consider the potential health implications for students and teachers, as well as explore innovative solutions to improve air quality in educational settings.

In another case study, Akanmu explored the possibilities of using hypothetical scenarios to facilitate skill development among industry professionals. He created a scenario where a commercial building faced energy efficiency and indoor air quality challenges, prompting engineers and building managers to collaborate on finding sustainable solutions that balanced environmental impact with prudent use of invested resources.

Akanmu also utilised hypothetical scenarios to foster learning and education in his research. By presenting complex concepts in a relatable and engaging manner, he empowered students, industry professionals, and communities to envision new ideas and innovations that could shape the future of indoor air quality and health and value delivery in sustainable building engineering.

Through interactive workshops and immersive learning experiences, Akanmu encouraged his audiences to apply theoretical knowledge to practical situations, cultivating critical thinking and problem-solving skills.

Furthermore, Akanmu's research on hypothetical scenarios served as a catalyst for innovation and risk management in the industry. By simulating potential challenges and emergencies related to indoor air quality and health and value delivery in sustainable building engineering, he helped industry professionals anticipate risks, plan for contingencies, and make informed decisions to protect the health and well-being of building occupants with the prudent use of invested resources by the developed solutions.

Through his innovative approach to research, Akanmu demonstrated the transformative potential of hypothetical scenarios in driving positive change in indoor air quality and health and value delivery in sustainable building engineering. His commitment to using art as a tool for education and problem-solving enriched the academic landscape and empowered industry professionals and communities to create healthier and more sustainable indoor environments for generations to come.

The effect of poor indoor air quality compromising human health and their capacity to perform tasks or solve problems in indoor environments decreased significantly due to improved practices in the industry and communities.

Many students, industry professionals, and communities acknowledged Akanmu and his research team's contribution to positive development. Akanmu also trained many undergraduate and graduate engineering students in using artistic-educational research to empower human development and promote healthy living and value-delivery practices.

Akanmu's innovative research in art education also impacted Hingland's Ministry of Education policies regarding teaching and learning theory and practice. Additionally, his research raised awareness that influenced the policies of the Ministry of Health and Ministry of Sustainable Built Environment's policies for promoting healthy indoor air and enhancing value delivery in sustainable building engineering.

Moreover, through various interviews, Akanmu educated students, industry professionals, and community members about the significance of improving indoor air quality to mitigate exposure to pollutants, which can reduce the risk of memory loss, cognitive impairment, and health problems.

The audience of Akanmu's research outputs also learnt how to improve their educational practices through critical and reflective thinking. Thus, the beneficiaries of Akanmu's research works were not limited to people in the built environment industry. His research was geared to human development. Akanmu's research outputs were in the form of public speaking and published works in public domains. His published works were accessible to audiences worldwide. He also has publications in peer-reviewed journals. Akanmu also gave several interviews. An example of the interview exchange between Akanmu and a journalist is below.

"Akanmu: According to my artistic-educational research, understanding differs from knowledge because understanding questions the purpose and reason for acquired knowledge. The purpose of a thing is a statement of the problem the thing is meant to solve to achieve a particular goal. A reason or 'why' is the cause of the occurrence or existence of a thing.

On the other hand, knowledge is the awareness of the linkage between or organisation of the body of information acquired by sensory organs. Understanding is processed information. Knowledge is also processed information. However, understanding is a deeper form of processed information.

Skill is how processed information is used. Knowledge, understanding, and skills related to processed information can be broadly categorised as experience. The processing of information that forms the processed information is learning. Thinking is the tool for learning, and questioning is the tool for thinking. Stored experience (processed information) is the engine for questioning which aids thinking, and the thinking that aids learning."

Journalist: “So, it is a loop process. Learning forms experience, and experience shapes learning. I get it now. The loop process is what is known as memory. I said this because I learnt from a professor of neuropsychology that ‘Memory is the process in which the brain interprets (i.e., processing of), stores, and retrieves (processed and unprocessed) information.’

Thus, the quantity and quality of stored experience, the integrity of the storage, and the quality, quantity, and safety of the retrieval of stored experience for aiding learning matter to the quantity, quality, and safety of learning.”

Akanmu: “You see. Intelligence is the use of experience gained from learning to solve problems. The value delivery from the problem-solving exercise is a function of the human intelligence level. Thus, if memory is compromised, the intelligence level will be compromised. Any hazard that could increase the risk of human memory being compromised should be minimised as much as possible. Acute or chronic exposure to indoor air pollutants (e.g., $PM_{2.5}$) is an example of such hazards.

Exposure to $PM_{2.5}$ can be higher indoors than outdoors. Evidence in the literature suggests that exposure to chemical, biological, or physical-based $PM_{2.5}$ can compromise the capacity and integrity of brain parts responsible for interpreting information and storing and retrieving processed information (experience). The compromise is what leads to memory loss. Reduction of human exposure to indoor air pollutants reduces vulnerability to the loss.”

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As word of Akanmu’s pioneering work spread, he began to attract attention and recognition from educators, researchers, and industry professionals worldwide. His innovative approach to education, grounded in art, literature, and science principles, resonated with people from all walks of life, earning him a reputation as a visionary thinker and a leading voice in the field.

Akanmu’s effort was recognised and rewarded by his university. He was promoted to full professor, becoming the first Professor of educational practice in engineering. While Akanmu appreciated the recognition, he saw it as the icing on the “cake” because, for him, the “cake” for him was having the opportunity to embark on artistic-educational research that truly aligned with what gave him fulfilment in his career, satisfaction, and self-worth.

Akanmu did not pursue popular traditional scientific (pure) research, which he was very capable of doing but did not align well with his identity as artistic-educational research does. He deliberately chose the “Educational Practice” track because that was the track that truly aligned with his interests and passion.

Akanmu’s university had two other tracks for faculty promotion: the “Pure and Applied Research” track and the “Industry Practice” track. Akanmu was not eligible for the industry practice track because it was meant for people with considerable working experience in the industry.

Before Akanmu, no one on the educational practice track was promoted to full professor. Many of the educational practice track faculty retired at the Associate Professor rank. Akanmu knew this but pursued the educational practice because he focused more on his internal validation. So, when Akanmu became a Full Professor, the promotion received huge attention at the University of Lambaba and the country, Hingland.

As Akanmu reflected on his journey—from his childhood to his groundbreaking work in artistic educational research—he realised that the most profound lesson he had learnt was the importance of prioritising internal validation over external validation.

Akanmu encountered skepticism, resistance, and criticism throughout his years of dedication to understanding and educating people about indoor air quality, health, and value delivery in sustainable building engineering. Some doubted his decision to pursue the educational practice track, given his capability to excel in the pure and applied research track. However, he remained unwavering in his belief that true fulfillment arises from staying true to one's principles, following one's passion, and giving valueto others, regardless of external validation or recognition.

Akanmu's commitment to internal validation fuelled his perseverance in the face of adversity and enabled him to make a meaningful impact on the world around him. By prioritising his values, beliefs, and passions, he contributed significantly to the transformation of the academic, industry, and community landscapes, inspired countless individuals to think critically and creatively, and paved the way for a brighter, more sustainable future.

Akanmu's life journey was a powerful reminder that true success and fulfilment could only be found by looking inward and staying true to oneself. By trusting in his abilities, following his passion, and embracing his unique vision, Akanmu achieved his dreams and left a lasting legacy that would inspire future generations.

As he continued on his path, guided by the light of internal validation, Akanmu knew that the possibilities for positive change were limitless. Years later, Akanmu became a Distinguished Professor of Educational Practice in Engineering. Professor Akanmu was well respected by his students, colleagues in the academia, the industry, and the community. Professor Akanmu Abijah has now retired from the University of Lambaba, Hingland. He still holds a connection with the university as Professor Emeritus. **The End**!