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University of Moratuwa

CONFERENCE PROCEEDINGS

3rd International Research Conference – 2024

''Exploring New Frontiers: Innovative and Cross-Disciplinary Approaches to Sustainable Engineering Practices''

18 DECEMBER 2024 | ITUM, HOMAGAMA, SRI LANKA

Research Unit
Institute of Technology University of Moratuwa

Foreword

It is a privilege to publish the Proceedings of the 3rd International Research Conference of the Institute of Technology University of Moratuwa (ITUM-IRC 2024). The theme for this year, "*Exploring New Frontiers: Innovative and Cross-Disciplinary Approaches to Sustainable Engineering Practices,*" itself reveals our commitment to promoting impactful research that will address global challenges across the world through innovation and collaboration.

The ITUM-IRC 2024 proceedings book is an annual publication, which carries the proceedings of the conference conducted for researchers, academics, professionals, practitioners and students from diversified disciplines under one roof for the exchange of ideas while showcasing high-profile research.

This book contains the extended abstracts presented at the 3rd International Research Conference of the Institute of Technology University of Moratuwa, Sri Lanka held on 18th December 2024.

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Editorial Committee Acknowledgements

The Editorial Committee is proud to present the Proceedings of the 3rd International Research Conference of ITUM (ITUM-IRC 2024), featuring outstanding research contributions by scholars from diverse disciplines. This volume is the result of a rigorous double-blind review process and dedicated teamwork, ensuring the highest standards of academic quality.

We sincerely thank the authors for sharing their valuable research and the reviewers for their thorough evaluations, which significantly enhanced the quality of the submissions. Your expertise and dedication to academic excellence have been invaluable.

Our appreciation also goes to the Organizing Committee and technical team, whose commitment to accuracy, consistency, and timeliness in preparing this proceedings book is highly commendable.

We are confident that the proceedings of ITUM-IRC 2024 will serve as a valuable resource for researchers, educators, and practitioners, fostering knowledge sharing and inspiring new solutions to global challenges.

Thank you to everyone who contributed to this publication.

Sincerely,

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ITUM International Research Conference 2024

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Message from the Director,
Institute of Technology University of Moratuwa

It is with great pride and enthusiasm that I send this message to the proceedings of the 3rd International Research Conference of ITUM 2024, an event that underscores the vital role of innovation and collaboration in shaping a sustainable future. This year's theme, "*Exploring New Frontiers: Innovative and Cross-Disciplinary Approaches to Sustainable Engineering Practices,*" reflects the profound challenges and opportunities we face in addressing global sustainability.

Innovation lies at the heart of engineering, but in today's rapidly evolving world, it must transcend traditional boundaries. We must embrace practices that are environmentally responsible, socially equitable, and economically sound. At ITUM, we are committed to fostering a culture of exploration and creativity that drives transformative change, from renewable energy research to sustainable manufacturing processes.

Our efforts must also be inherently collaborative. The complexity of today's global challenges - climate change, resource scarcity, and urbanization require solutions that integrate diverse disciplines. By bridging gaps between engineering, environmental science, and social sciences, we can uncover synergies that redefine the way we design and implement sustainable systems.

This conference is not just a forum for sharing research but a call to action. The ideas presented here have the potential to shape the world for generations to come. I encourage all participants, researchers, speakers, and students to engage with curiosity and determination, fostering partnerships that advance the boundaries of knowledge and innovation.

I extend my heartfelt gratitude to the Head of the Research Unit and the Organizing Committee, sponsors, and participants who have made this event possible. Together, let us chart new paths and build a legacy of sustainability that will inspire future generations.

Thank you, and I wish you all a fruitful and inspiring conference.

Major General (Retd.) S. K. Thirunavukarasu RSP VSV USP
Director
Institute of Technology
University of Moratuwa

Message from the Head, Research Unit

The progress and sustainability of an academic community largely depends on its commitment to research. To strengthen this commitment, the ITUM Research Unit was established to provide guidance and support to academic staff, encouraging cross-disciplinary research that contributes to the advancement of society.

The Research Unit is proud to have successfully organized the ITUM-IRC 2024, the annual Research Conference, which was made possible through the continuous support of ITUM leadership and generous sponsorships from industry partners.

ITUM-IRC 2024 offers an extensive platform for disseminating the research findings of ITUM staff, students, other academic institutions, and industry stakeholders. This year's conference proceedings include a rich collection of 40 extended abstracts across five tracks, all under the theme: *Exploring New Frontiers: Innovative and Cross-Disciplinary Approaches to Sustainable Engineering.*

As the Head of the Research Unit, I deeply appreciate the untiring efforts of the membership of the Research Unit in promoting research, and I wish to place on record my sincere gratitude for all who contributed to the success of ITUM-IRC 2024.

MMPD Samarasekara
Head
Research Unit ITUM

Message from the Conference Chair, ITUM-IRC 2024

Let me welcome you with great pride and a deep sense of gratitude to the 3rd International Research Conference of the Institute of Technology, University of Moratuwa (ITUM-IRC 2024). The theme for this year, "*Exploring New Frontiers: Innovative and Cross-Disciplinary Approaches to Sustainable Engineering Practices*" highlights the critical need for innovative solutions and collaborative efforts across traditional boundaries to tackle global challenges.

This event represents months of dedicated preparation, collaboration, and shared enthusiasm for advancing knowledge and innovation. The theme of this year's conference reflects the urgency and importance of sustainable engineering in today's world. It highlights the need for innovative solutions that cross traditional boundaries, bringing together diverse perspectives to address the complex challenges.

The initial call for extended abstracts spanned five thematic tracks, showcasing a diverse range of topics in engineering and interdisciplinary approaches. Based on the submissions received, the conference program was carefully curated, with some tracks being combined and others distributed across multiple sessions to accommodate the richness and depth of research. This thoughtful structuring ensures engaging discussions and fosters knowledge-sharing among participants.

I want to express my heartfelt gratitude to the Organizing Committee, whose tireless efforts have made this conference possible, and to the reviewers for ensuring the highest standards of academic excellence. A special thank you to all the authors who contributed their valuable research.

We are fortunate to have an esteemed keynote speaker and a special speaker whose expertise and insights promise to inspire and provoke meaningful discussions. I am also deeply appreciative of the administration of ITUM and our sponsors, whose support has been vital in bringing this conference to fruition.

It provides a vital platform for academics, researchers, and industry professionals, and experts to have meaningful discussions, share pioneering ideas, and build networks across disciplines. The range of topics to be covered in this conference illustrates the nature of modern research and its applications toward finding sustainable solutions for the future.

Together, let us contribute towards shaping a future that is innovative and will be sustainable for generations to come.

Thanks for being part of this journey.

Kalpana Galappaththi
Conference Chair
3rd International Research Conference
Institute of Technology University of Moratuwa

Technical Session A

Technical Session B

Technical Session C

Technical Session D

Technical Session E

Technical Session F

Keynote Speech

Dr. Ishara Dharmasena

Wolfson School of Mechanical, Electrical and Manufacturing Engineering
Loughborough University
England

SUPER-SMART TEXTILES: A CROSS-DISCIPLINARY JOURNEY TOWARDS FUTURE WEARABLE TECHNOLOGIES

Synopsis

Super-Smart Textiles are a novel wearable technology that converts natural body movements into electrical signals through advanced fibre materials. The technology operates based on static charging and electrostatic induction at the fibre level. Super-Smart Textiles can function as self-powered active sensors to monitor body movements and physiological parameters, or as energy generators to operate low-power electronics. Unlike conventional wearables, this technology integrates seamlessly with clothing and has the potential to provide excellent electrical performance, autonomous operation, wearability, low cost, and comfort. The applications of this technology are explored in remote health sensing, sports, communication, and personal electronics. Herein, we will discuss our pioneering research in Super-Smart Textiles: a cross-disciplinary journey from theory to devices and wearable applications.

Special Speech

Assoc. Prof. (Mrs.) WBM Thoradeniya

Division of Civil Engineering Technology
Institute of Technology, University of Moratuwa
Sri Lanka

MULTIPLE INTELLIGENCES AND SUSTAINABILITY IN THE ENGINEERING INDUSTRY

Synopsis

Traditionally, intelligence was limited to the "3Rs": Reading, Writing and Arithmetic. Students entering engineering study programs were expected to excel primarily in mathematical intelligence. In 1983, Howard Gardner introduced the theory of multiple intelligences, revolutionizing our understanding of cognitive abilities.

In the context of engineering education, recognizing and integrating these diverse intelligences can have numerous positive impacts on students' learning experiences. Further, identifying the multiple intelligences possessed by engineering practitioners is crucial for individual career progression and professional success which, in turn, significantly contributes to the sustainability of the engineering industry.

THE IMPACT OF GLOBAL CRUDE OIL PRICE FLUCTUATIONS ON THE ECONOMY OF SRI LANKA WITH A SPECIAL REFERENCE TO THE TOURISM AND AGRICULTURAL SECTORS

D.A.D. Lavindika[1*], S.C. Mathugama[2], and D.R.T. Jayasundara[3]

[1,3]University of Moratuwa, Sri Lanka,

[2]Institute of Technology University of Moratuwa, Sri Lanka

dulshidodangoda@gmail.com[1*], mathugamas@itum.mrt.ac.lk[2], ravindij@uom.lk[3]

ABSTRACT: This research paper analyses the relationship between global crude oil price fluctuations and their impact on Sri Lanka's economy, with particular emphasis on the tourism and agriculture sectors. Utilizing secondary data sources from the Central Bank of Sri Lanka (CBSL), the study examines the period from 1984 to 2023 and employs statistical methods to evaluate how changes in oil prices affect these sectors. This reperch paper centres around the objectives of identifying trends and patterns in global crude oil prices, tourism revenue, and agricultural contributions to Gross Domestic Product (GDP), and to assessing the correlation between these variables. As per the findings, oil price volatility has a significant influence on both sectors. It is evident that the tourism sector has shown resilience with a moderate positive correlation with oil prices which can be attributed to Sri Lanka's positioning as a budget-friendly travel destination. Conversely, the agricultural sector shows a negative trend and a strong negative correlation with rising oil prices. This can be understood as the sector's high sensitivity to increased input costs and economic pressures. The autoregressive nature of both sectors, observed through the Autoregressive Integrated Moving Average (ARIMA) model is a clear indication of a dependency of future outcomes on past trends. As per the findings it can be concluded that while the tourism sector displays agility to a greater extent, the agricultural sector is highly affected by increases in oil prices and requires assistance and strategic measures to mitigate adverse impacts. The paper highlights the necessity for continuous efforts and longer-term solutions to address the dual effects of oil price volatility. It is recommended to improve the models by incorporating additional variables into the analysis and incorporating predictive tools. This research paper provides valuable insights for policymakers and industry stakeholders in navigating the economic impacts of crude oil price variability.

Keywords: agricultural sector, ARIMA, crude oil prices, economy, tourism sector

1. INTRODUCTION

Sri Lanka depends on imports to fulfil its domestic crude oil requirements, exposing the economy to fluctuations in the global crude oil market. The agricultural sector, which contributes over 7% to the country's Gross Domestic Product (GDP), is a direct user of crude oil as it heavily relies on oil for inputs and distribution. Similarly, the tourism sector, a key determinant of foreign exchange income, also relies significantly on crude oil inputs and logistics throughout the value chain. Existing research, including studies by Wanigasooriya (2018) and Lanzi (2016) has analysed the impact of oil price fluctuations. However, specific studies focusing on Sri Lanka and these two sectors are limited.

This research paper evaluates data available from 1984 to 2023 to understand the impact of oil price volatility on Sri Lanka's tourism and agriculture sectors. The primary objectives of the research include identifying patterns in oil prices, tourism revenue, and agricultural GDP contributions, analysing correlations between these variables, and employing time series and regression analyses to model their relationships. This paper aims to provide valuable insights on the topic and facilitate informed decision making.

2. METHODOLOGY

The research paper adopted a quantitative research approach to evaluate the impact of global crude oil price fluctuations on Sri Lanka's tourism and agricultural sectors. Statistical methods including time series and regression analysis were used to analyse the observed data spanning almost four decades from 1984 to 2023. This longitudinal data analysis captured long-term trends and fluctuations in oil prices and their effects on the tourism and agricultural sectors

Descriptive Statistics: Descriptive statistics were employed to measure key characteristics of the dataset, including the mean, median, standard deviation, skewness, and kurtosis. Additionally, a trend chart was utilized to visually illustrate the relationships among variables over time, providing a graphical representation of how the variables evolved over the years.

Simple Linear Regression: Simple linear regression was applied to assess the relationship between one   dependent and one independent variable, using Ordinary Least Squares (OLS) for parameter estimation. The model assumptions include linearity, no autocorrelation, homoscedasticity, and normality of residuals (Mayel, 2022).

$$Y_t = \beta_0 + \beta_1 X_t + \epsilon_t \ldots\ldots\ldots\ldots\ldots (1)$$

where; Y_t : dependent variable at time X_t : independent variable at time t
β_0 : intercept β_1 : coefficient
ϵ_t : error term or residual at time t

The error term is crucial to the model's assumptions, with the main assumptions being linearity, independence, homoscedasticity, and normality.

Univariate Time Series Analysis: Stationarity was tested using the Augmented Dickey-Fuller test. The Autoregressive Moving Average (ARMA) models were fitted using Box-Jenkins methodology to capture temporal patterns.

a. Stationarity Assessment: The stationarity ensured that the statistical attributes of the information remained stable over time and the tools such as Augmented Dickey Fuller test could be used to determine stationarity (Petchko, 2018).

b. The Box-Jenkins Methodology and the ARMA Model Fitting: This methodology uses a finite number of parameters namely Autoregressive process (AR), Moving Average process (MA) and Autoregressive Moving Average (ARIMA) process. A model that contains both AR and MA parameters is called an "ARMA" model. These models are very efficient in such time series data that is known to be temporal in nature due to the presence of the AR, and MA components (Camporeale, Wing, & Johnson, 2018).

$$Y_t = c + \phi_1 Y_{t-1} + \phi_2 Y_{t-2} + \cdots + \phi_p Y_{t-p} + \theta_1 e_{t-1} - \theta_2 e_{t-2} + \theta_q e_{t-q} + e_t \ldots\ldots\ldots (2)$$

Y_t : observed value of the time series at time t c : constant

ϕ_1, ϕ_2, ϕ_p : autoregressive coefficients representing the relationship between the current value of the time series and its past p values
$\theta_1, \theta_2, \theta_q$: moving average coefficients representing the relationship between the current value of the time series and the past q error terms

e_t : white noise error term assumed to be normally distributed with mean zero and constant variance

The model adequacy is evaluated through residual diagnostics. Residual autocorrelation was measured by the Ljung-Box Q test (Hee & Ha, 2004), heteroskedasticity was checked using the Lagrange multiplier (LM) test for autoregressive conditional heteroskedasticity (ARCH LM test) (Sjölander, 2011) and normality of residuals was assessed by the Jarque-Bera (JB) statistic (Thadewald & Büning, 2007).

3. RESULTS AND DISCUSSION
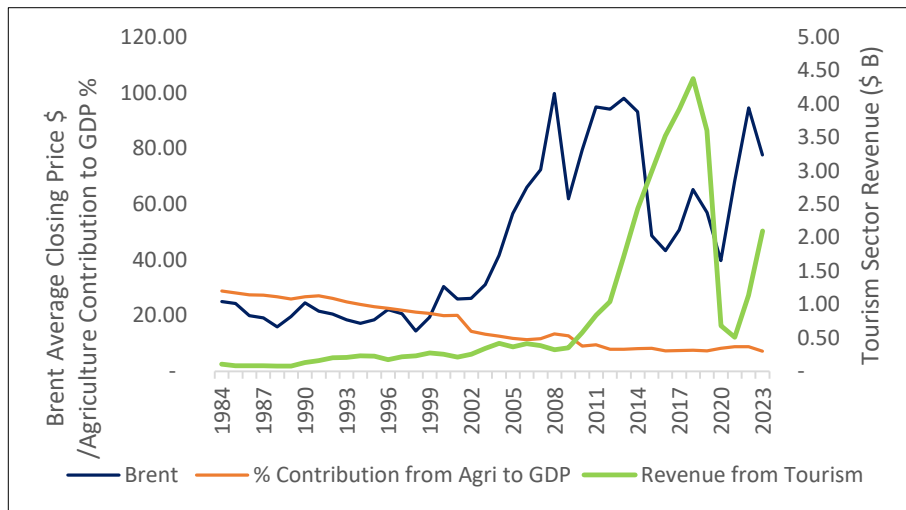
Fig. 1. Trend for Brent, Agriculture contribution and Tourism revenue

Crude oil prices have exhibited a significant upward trend over time with high volatility, influenced by global events. In contrast, the agriculture sector's contribution to GDP has steadily declined, reflecting a shift towards other sectors (see Fig.1). The tourism sector's revenue has been increasing, with fluctuations due to external factors. The correlation analysis reveals a strong negative relationship of -0.8 between crude oil prices and the agriculture sector's GDP contribution, while tourism revenue shows a weaker positive correlation of 0.41 with oil prices.

The regression analysis of the agricultural sector and tourism sector revenue relative to Brent crude oil prices reveals distinct insights. For agriculture, a linear regression model indicates a significant negative relationship with Brent prices, with an R^2 of 63%, though residuals show high autocorrelation (Durbin-Watson = 0.52). In contrast, the tourism sector shows a positive correlation with Brent prices when using natural logarithms, with an R^2 of 51% and significant coefficients (Durbin-Watson = 1.30). Since the model carries weaknesses, including moderate correlation for tourism revenue and autocorrelation of residuals for both agriculture sector's GDP contribution and tourism revenue. To address these limitations, time series analysis is recommended as a more robust approach.

The ARIMA modelling of the agricultural sector's contribution to GDP involves examining various AR and MA models using Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) plots. The ARIMA (1,2,2) model was selected as the optimum based on the lowest Akaike's Information Criteria (AIC) and the significant of its AR and MA components. Residual diagnostics indicate that the model's residuals are white noise, normally distributed, and exhibit homoskedasticity. The AR and MA roots are within the unit circle, confirming the model's stationarity and invertibility. The ARIMA (1,2,2) model demonstrates a good fit with an R^2 of 78% and a root mean squared error of 0.7, showing an acceptable performance.

For the tourism sector's revenue data, ACF and PACF plots of the second difference were used to assess potential ARIMA models. The ARIMA (1,2,1) model was identified as optimal due to its lowest AIC and significant AR and MA components. Residual diagnostics confirmed that the residuals are white noise, normally distributed, and homoscedastic. The ARIMA (1,2,1) model's AR and MA roots also lie within the unit circle, ensuring stationarity and invertibility. The model demonstrates reasonable performance with an R^2 of 67% and a root mean squared error of 0.8. Fitted values align well with the actual data, indicating a good model fit (Fig.2 and 3).
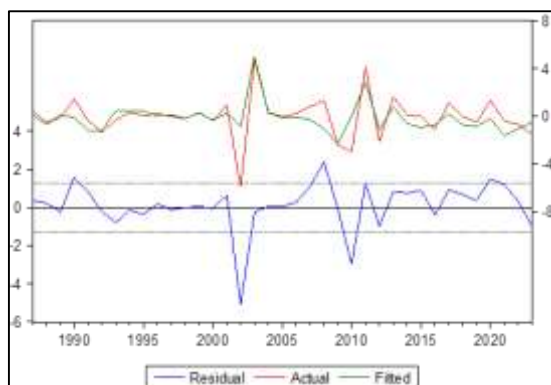
Fig. 2. Actual Vs Fitted model for Agriculture
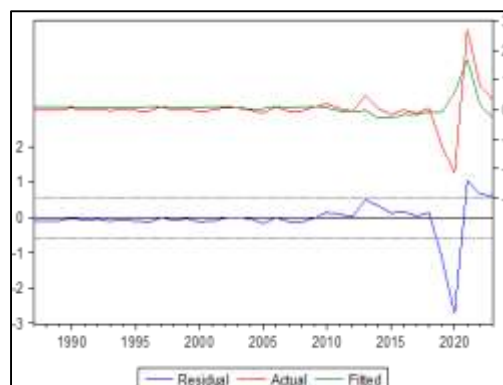
Fig. 3. Actual Vs Fitted model for Tourism

4. CONCLUSION

From 1984 to 2023, the average closing price of crude oil showed a general rising trend, influenced by geopolitical events, technological advancements, and market dynamics. Notable disruptions included the Gulf War, 2008 financial crisis, and the shale oil revolution. During this period, Sri Lanka's agricultural sector's contribution to GDP gradually declined, reflecting its reduced relative importance due to industrialization, urbanization, and international economic shifts. The sector's average contribution was 16.42%, but its revenue was unstable, with a high standard deviation of 7.92%. Conversely, Sri Lankan tourism revenue, with an average of \$0.88 billion, showed resilience to crises like the 2006 tsunami, civil war, and COVID-19.

The correlation analysis indicated a strong negative relationship between the agricultural sector's GDP contribution and oil prices (Pearson coefficient of -0.8), while tourism revenue and oil prices had a moderate positive correlation (0.41). OLS regression revealed that increasing oil prices negatively impacted crop yields but positively affected tourism revenue, likely due to Sri Lanka's status as an affordable tourist destination. However, since the OLS regression has limitations including autocorrelation and moderate correlation, adjustments including transforming the variables and considering Generalized Least Squares (GLS) could be looked at.

ARIMA models for both sectors demonstrated the influence of past performance on current results. The agricultural sector's model had high AR (1) and MA (2) coefficients, while the tourism sector's model highlighted significant AR (1) and MA (1) components. The models had R^2 values of 0.78 and 0.67, respectively, indicating their effectiveness in predicting future trends. Overall, the findings underscore the need for strategic planning in the agricultural sector and highlight the stability of the tourism industry amid oil price volatility.

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TRANSFORMING TRADITIONAL PEDAGOGIES: THE IMPACT OF ONENOTE ON UNIVERSITY TEACHING AND LEARNING PRACTICES

J.M.P. Gunasekara[1*], M.D.G.M. Gamage[2], and U.U. Sanjeewani[3]

[1,2,3] Institute of Technology University of Moratuwa, Sri Lanka

malingunasekara@gmail.com[1*], g2madhusha@gmail.com[2], upulisanjeewani.u@gmail.com[3]

ABSTRACT: The spread of COVID-19 around the world led to the lockdown of many universities in the world posing significant challenges for conducting traditional face-to-face lectures. As a result, both students and educators had to transition to online teaching and learning, creating opportunities to explore various tools and applications for delivering complex subject content in an understandable way. In this context, this paper presents how Microsoft OneNote can be used as a digital note-taking application for both students as well as educators to deliver the subject content in a user-friendly manner utilizing its features of the OneNote for engaging and user-friendly content delivery. The survey result reveals that a higher percentage of students prefer digital notetaking for their learning at the university.

Keywords: digital note, leaning, OneNote, online learning

1. INTRODUCTION

The COVID-19 pandemic caused a transition to online learning, posing distinct challenges for university teaching worldwide (Senthilkumar, 2022). This shift was particularly difficult in areas such as engineering and medicine due to the complexity of the subject content. Specifically, intricate illustrations and the application of mathematical formulas posed a significant challenge. The lockdown of cities disrupted traditional classroom teaching methods (Wicaksono, 2024). However, the lockdown encouraged students to continue their academic work online using electronic devices and a variety of software applications (Grijalva-Borja et al., 2020). This situation presents an opportunity for educators and students to explore new tools and strategies to overcome the challenges associated with online teaching and learning.

Moreover, digital note-taking applications emerged with advanced features designed to provide a user-friendly interface with flexibility. Several digital note-taking applications such as Evernote, Notion, Obsidian, Joplin, Apple Notes and OneNote have immense popularity (Harry Guinness, 2024) each offering unique features tailored to various user needs.

In this study, the Microsoft OneNote digital note-taking application was used to create a bridge between students and educators in the teaching and learning process. Several factors, such as cost-free accessibility, handwriting facility, quick content updates, the ability to add web links, and the option to insert documents in print format, are attractive features that help engage students in the learning process.

To evaluate student engagement with OneNote application, a digital book was created for the Control System Module offered in the third semester of the Engineering diploma curriculum. Student interaction with the features available in OneNote was identified through a survey. The results of this study are expected to provide valuable insights into how Microsoft OneNote can enhance traditional teaching and learning approaches, potentially leading to more interactive and adaptable learning experiences for students in higher education.

2. METHODOLOGY

The layout of the Microsoft OneNote is similar to a typical notebook which includes sections and pages. The content for the module can be organized within a notebook created in Microsoft OneDrive allowing access from any device including smart phones, laptops or tablets.

In this study, the content for the 3rd semester module was created in OneNote titled "Studentcopy-ME2302". The sections (L1, L2, L3 etc.) were named according to the lecture topics. Each lecture topic includes various elements such as topic introduction, in-class discussion, tutorial questions, references. These elements were organized into pages under each section as shown in Fig. 1.
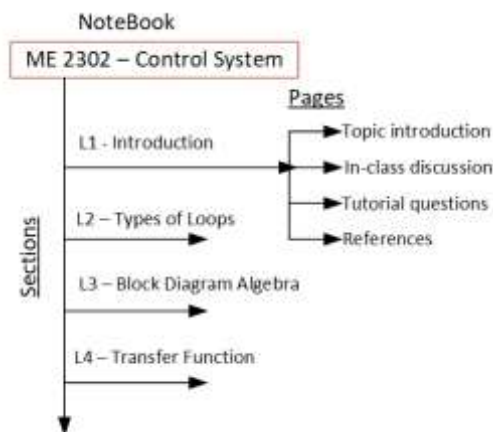
Fig. 1. Layout of OneNote Created for the ME2302 Module

A OneNote book was created in OneDrive and shared with the student community via a link. The content of the OneNote was developed through the features available, such as the drawing facility (to annotate content), resources addition (web link, pdf, docx, etc.), tagging, voice recording. A Google form was created to collect students' interest in using OneNote as a digital note-taking application for their learning process. The details of the survey and its findings are presented in the Results and Discussion section.

3. RESULTS AND DISCUSSION

Responses from 100 students enrolled in the ME2302 module were selected for the study. The responses were summarized in Table 2. This survey focused on collecting data in three important areas such as, (i) methods used to access OneNote, (ii) how students interact with the features of OneNote and (iii) students' views on digital note-taking compared to traditional handwritten note taking.

Table 1. Questionnaire

Question	*Options*
(a) How did you access OneNote?	Smart phone / Laptop / Tablet
(b) Which feature/s of OneNote are you interested in?	• Quick update of the content • Organization structure • Content can be viewed later • Facility for handwritten content • Adding web links (YouTube etc.) • Adding print notes
(c) Your feedback on using OneNote for teaching at university?	• It is good tool for learning as students can view the content. • Handwritten notetaking is better than digital notetaking for students. • I have no idea about OneNote tool.
(d) Are you using OneNote for your work now?	Yes / No

Table 2. Students' Responses

(a) Device used to access OneNote		
Smart Phone – 56%	Laptop – 82%	Tablet – 6%

(b) Students' interest in the features of OneNote	Percentages
Quick updates of content	71%
Organization structure (sections and pages)	65%
Content can be viewed later	56%
Facility for handwritten content	50%
Adding web links	43%
Adding print notes	31%

(c) Digital vs. Handwritten notetaking	
Digital notetaking is good tool for university learning	90%
Handwritten is better than digital note- taking	34%
No idea of digital notetaking	4%

(d) Further use of OneNote	
Yes	67%
No	33%

The survey results show that students use a variety of OneNote capabilities and engage with components that enhance their learning strategies. Additionally, a significant number of students (90%) agreed that switching from traditional paper-based notetaking to digital notetaking was an effective approach for learning at university.

OneNote supports educators in actively engaging students in the learning process in a flexible manner with features that help clarify complex subject areas. Its numerous advanced functionalities promote greater creativity and effective teaching methods. In fact, the steep learning curve of OneNote motivates over 67% of students to engage with it for their future work. Additionally, this study identified that around 4% of students are unaware of the OneNote application which may pose a challenge in shifting their mindset for taking advantage of technological advancements in the learning process.

4. CONCLUSION

Universities have incorporated several tools and techniques for teaching and learning in response to global technological advancements. This research examines student engagement with digital notetaking through OneNote, revealing that its features are preferred by the student community for enhancing the learning process. Transforming traditional teaching with the help of OneNote is a one of the ways to enhance student learning while providing educators with the flexibility to present subject content more effectively. This study can be expanded by investigating how students and educators engage with various other digital note-taking applications and analyzing their benefits and drawbacks.

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INTEGRATING SOLAR PHOTOVOLTAIC SYSTEMS FOR ENERGY MANAGEMENT: A CASE STUDY OF A HIGHER EDUCATIONAL INSTITUTE

G. K. Jayatunga[1*] and M. Wickramathilaka[2]

[1, 2] Institute of Technology University of Moratuwa, Sri Lanka

gayanij@itum.mrt.ac.lk[1*], manjulad@itum.mrt.ac.lk[2]

ABSTRACT: This paper presents a study on integrating solar energy into a higher educational institute to meet Sustainable Development Goal 7.1, which focuses on universal access to affordable, reliable, and modern energy services. This study focuses on implementing solar photovoltaic (PV) systems at the Institute of Technology, University of Moratuwa (ITUM), Sri Lanka to address rising energy costs and reduce carbon emissions. ITUM, which accommodates approximately 1,600 resident students and 200 staff spent approximately 33 million LKR on energy in 2022. This research proposes the installation of 450 kWp solar PV system to cover 65% of the institute's daytime energy consumption, generating an estimated 57,956 kWh per month. The system is projected to provide monthly savings of 2.17 million LKR. With a total investment of 48.04 million LKR and an estimated payback period of 2 years, the solar installation will reduce ITUM's carbon footprint by 395 MT of carbon dioxide annually. The integration of solar energy at ITUM demonstrates a viable approach to achieving financial savings, improving energy sustainability, and fostering environmental responsibility within educational institutions.

Keywords: carbon footprint, energy management, higher educational institute, solar PV energy

1. INTRODUCTION

Energy management in higher education institutions is crucial to ensure not only the sustainability of educational programmes but also the maintenance of a minimum carbon footprint. Many organizations focus on strategies to reduce energy costs and carbon footprints with concern for increasing energy prices and the impacts of climate change. Target 7.1 of the United Nations' Sustainable Development Goals ensures universal access to affordable, reliable, modern energy services (Parra et al., 2020). The sustainability of educational programs relies on the availability of infrastructure and resources needed for the smooth operation of educational programs, research and development, and staff and student welfare. Energy costs can be reduced by various strategies such as energy conservation by efficient usage of equipment and instruments and switching to cost-effective renewable energy sources. Many strategies and practices are focused on reducing energy consumption in universities and higher educational institutes by using energy-efficient technologies and promoting sustainable practices among students and staff, such as encouraging the use of public transportation, rainwater harvesting, recycling, and reducing waste. For higher education institutes, energy management not only supports global sustainability efforts but also ensures the continuous delivery of academic programs and the well-being of future leaders (Purcell et al., 2019).

The Institute of Technology, University of Moratuwa (ITUM), is a prominent technical education provider in Sri Lanka, accommodating approximately 1,600 resident students and 200 staff members. ITUM has experienced a rapid increase in energy costs from 22 million LKR in 2020 to 33 million LKR in 2022. The COVID-19 pandemic temporarily reduced energy consumption due to limited on-campus activities. However, when the operations returned to normal, energy usage surged. These rising energy expenses, coupled with a significant increase in water costs, have placed a substantial financial burden on the Institution (ITUM, Annual Report 2020, n.d.; ITUM, Annual Report 2022, n.d).

Conducting energy audits can help identify areas where energy is wasted, enabling targeted improvements. Furthermore, integrating renewable energy sources, such as solar PV systems or wind turbines, can significantly reduce dependency on non-renewable energy. Energy saving in higher educational institutions is important for several reasons. Firstly, it reduces operational costs, allowing institutions to allocate more resources to educational programmes and student welfare. Secondly, implementing energy-saving measures promotes sustainability and environmental

responsibility, aligning with global efforts to combat climate change. Additionally, these initiatives can enhance the institution's reputation.

This study explores the feasibility of installing a 450 kWp solar photovoltaic (PV) system at ITUM to address rising energy costs and reduce dependency on non-renewable energy. Solar energy is an ideal solution, not only for lowering electricity bills but also for contributing to the sustainability goals of the country. By utilizing renewable energy, ITUM can reduce its carbon footprint, lower operational costs, and promote a culture of sustainability among students and staff. This investigation aims to provide actionable recommendations to meet a substantial percentage of the institution's daytime energy demand using solar PV systems, estimate financial savings from reduced electricity bills, and determine the reduction in carbon emissions.

2. METHODOLOGY

Past electricity bills of the institute were collected and analyzed to determine the monthly and annual energy consumption. Table 1 shows the average monthly consumption of electricity during off-peak time, daytime, and peak time. The electricity tariff charged by Ceylon Electricity Board and the corresponding cost of energy consumption during three time slots are also shown in Table I (Business With CEB, n.d.). Major consumers of the institute were identified as refrigeration and air conditioning systems. The air-conditioning system is operated solely in the administration buildings, some lecture halls and laboratories, and the auditoriums while student accommodations are not equipped with air conditioners.

Table 1. Monthly Energy Consumption in the Institute

Time of the Day	Current usage (kWh)	Tariff (Rs./kWh)	Cost of consumption (Rs.)
Off peak (2230 - 0530)	16,769	30.6	513,131.40
Day (0530 - 1830)	87,763	37.4	3,282,336.20
Peak (1830 - 2230)	20,930	45.9	960,687.00
Total	**125,462**		

The ITUM is located at a latitude of 6.7924° N and a longitude of 79.9641° E. The total surface area available in the institute for solar panel installations was identified by an analysis conducted using Google Earth (Google Earth, n.d.). The workable roof area was calculated to be over 5100 m². Figure 1 shows the view of the institute captured from Google Earth.

Fig. 1. View of ITUM Captured from Google Earth

In our study, a 450 kWp system was selected which is equivalent in size to 80% of the roof area approximately. The extra amount of energy generated in holidays or university vacations can be exported to the national grid, though this was not considered in the payback time calculation due to the unpredictable nature of the university's schedule. Monthly savings from solar energy utilization and the simple payback period are calculated with the use of the data shown in Table 2 (Ceylon Eco Solar (Pvt) Ltd, n.d.). The payback period was calculated by dividing the cost of the investment by the savings or revenue produced. Reduce carbon footprint by offsetting the need for energy produced from fossil fuels was estimated.

Table 2. Data Collected to Estimate the Payback Period and Reduced Carbon Footprint

Description	Amount	Unit
Average daily peak sunlight hours in Homagama	5.3	h
Derating factor due to temperature	0.9	-
Inverter efficiency	0.9	-
Approximate unit cost for 48V batteries	6000	Rs/Ah
Tariff at which solar energy is purchased by CEB (*Business With CEB*, n.d.)	23.18	Rs/kWh
Emission factor (*Ceb.Lk/Publication-Media/Planing-Documents*, n.d.)	0.568	Kg CO_2/kWh

3. RESULTS AND DISCUSSION

According to the market survey, the approximate cost of solar PV systems (including inverter and other accessories) is 350 USD per kW (Ceylon Eco Solar (Pvt) Ltd, n.d., About Us - First Energy, n.d.). Accordingly, the total investment will be approximately 48.04 million LKR while 2.17 million LKR can be saved from the electric city bill. The payback period will be a maximum of two years. Table 3 shows summarized details. The estimated area occupied by the proposed system is 4183m^2 (45,000ft^2), if the area occupied by 1kW solar PV is 100ft^2 approximately (Solartechadvisor.Com, 2022). The installation of the solar energy system will reduce the institute's carbon footprint by 395 MT of carbon dioxide per year.

Sustainability should be addressed not only in energy management but also in curriculum development, administration, and reporting culture (Ramos et al., 2015). Academic institutions have the potential to mitigate their adverse environmental impact while concurrently cultivating a sustainable culture that will prepare forthcoming leaders to tackle global issues.

Table 3. Details on Estimated Payback Period

Description	Value	Unit
Installed Solar PV capacity	450	kWp
Expected monthly generation from solar	57956	kWh
Approximate unit cost of solar PV & Inverter	350	USD/kW
Dollar rate as at 07-09-2024 (*Exchange Rates / Central Bank of Sri Lanka*, n.d.)	305	Rs.
Total Investment	48.04	Rs. Million
Monthly savings from electricity bill	2.17	Rs. Million
Payback period	23	months
	2	years

4. CONCLUSION

The proposed installation of a 450 kWp solar photovoltaic (PV) system is expected to significantly reduce the electricity costs and carbon footprint of the institute. With a total investment of approximately 48.04 million LKR and an estimated simple payback period of two years, the system will generate around 57,796 kWh of electricity per month. 65 % of energy consumption will be covered during the daytime. Combined with a monthly savings of 2.17 million LKR on electricity bills, the financial viability of the project is well-supported. Furthermore, the project will have a significant environmental impact, reducing the institute's carbon footprint by 395 MT of CO_2 annually. Overall, the proposed solar pv system becomes an ideal solution for energy cost reduction of ITUM and the National energy crisis.

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INCORPORATING RECOVERED CARBON BLACK INTO SOLID TYRE TREAD COMPOUNDS

W. R. R. Chamodani[1*], J. C. Jayawarna[2], and A. D. Weerakoon[3]

[1,3] Polymer and Chemical Engineering Technology Division, Institute of Technology University of Moratuwa, Sri Lanka.

[2]LAUGFS Corporation (Rubber) Ltd, Sri Lanka.

rumesha.chamodanii@gmail.com[1*], janadara@laugfs.lk[2], amalidhanu22@gmail.com[3]

ABSTRACT: This paper presents the experimental results obtained from a study on incorporating recovered Carbon Black (rCB) produced from the pyrolysis process of end-of-life tyres into solid tyre tread compounds. The purpose of this study is to expand technical knowledge on the use of rCB as a sustainable alternative to virgin carbon black (vCB). The primary objective is to contribute to environmental sustainability by reducing reliance on commercial grade-N330 CB and promoting circular economy practices within the rubber industry. Earlier studies have shown that rCB has lower reinforcement properties compared to vCB and vCB cannot be completely replaced with rCB. Therefore, in this study the effect of rCB incorporation on the rheological and mechanical properties of the solid tyre tread compound was assessed and compared with those obtained from vCB (N330) alone as the controlled sample. The RCB sourced from an Indian supplier was evaluated through incremental addition of RCB in addition to the existing N330 phr level in the formulation at 5, 10, 15, and 20 phr levels. According to the results, with the increase in rCB loading mechanical properties and rheological properties of the compounds were lower than those of the vCB loaded compounds. Despite this, interesting performances can be achieved when rCB is incorporated into formulations at 10 phr in additon or by replacing the N330 load from 10 phr of rCB in the compounds. The mechanical and rheological properties of the 10 phr rCB reinforced compounds matched those of 100% vCB reinforced compounds. The study concludes that a combination of rCB and conventional CB grade- N330 can be used to achieve an optimal balance of reinforcement and desired properties, supporting the use of rCB as a viable alternative in tyre tread compounds.

Keywords: circular economy, environmental sustainability, recovered carbon black, tread compound, virgin carbon black

1. INTRODUCTION

The growing global demand for tyres, projected to exceed 2.9 billion units annually which may cause significant environmental challenges due to the generation of approximately 17 million tons of tyre waste each year (Dwivedi et al., 2020). Waste tyres, composed of natural and synthetic rubbers, carbon black (CB), and additives, are resistant to degradation and difficult to recycle effectively, making waste tyre management a global concern (Dwivedi et al., 2020). Carbon black, a key reinforcing filler in rubber compounds, enhances mechanical properties, durability, and wear resistance of tyres. However, traditional CB production via partial hydrocarbon combustion releases carbon dioxide and polycyclic aromatic hydrocarbons (PAHs), contributing to environmental concerns (Cardona et al., 2018). These challenges have driven interest in sustainable alternatives such as recovered carbon black (rCB) (Zhong et al., 2019).

1.1. Pyrolysis and Recovered Carbon Black (rCB)

Pyrolysis offers a promising solution to reduce tyre waste and the carbon footprint of CB production. This process thermally decomposes tires in the absence of oxygen, yielding pyrolytic oil, gas, and recovered carbon black (rCB) (Dwivedi et al., 2020; Cardona et al., 2018). rCB retains many of the properties of virgin CB (vCB) but contains impurities like ash and carbonaceous deposits, which can limit its reinforcing efficiency (Dwivedi et al., 2020). Although rCB can be used as a partial or full substitute for vCB, its performance depends on the pyrolysis process and post-treatment methods (Urrego Yepes et al., 2021). Treatments such as acid washing and heat treatment improve rCB's purity and surface activity, enhancing compatibility with rubber matrices (Dwivedi et al., 2020).

1.2. Incorporating Recovered Carbon Black in Solid Tire Compounds

Solid tyres, used in industrial and heavy-duty applications, demand tread compounds with high durability and wear resistance. Traditionally, vCB has been preferred due to its superior reinforcing

properties (Zhong et al., 2019). However, incorporating rCB offers a sustainable alternative as the tire industry prioritizes environmental solutions. Challenges with rCB, such as lower surface area and higher ash content, can reduce its reinforcing efficiency compared to vCB. Inorganic impurities, including zinc oxide and silica, may weaken filler-rubber interactions, impacting mechanical properties such as tensile strength and abrasion resistance (Dwivedi et al., 2020; Cardona et al., 2018). However, optimizing pyrolysis and post-treatment processes can improve rCB's performance, making it suitable for specific applications (Urrego Yepes et al., 2021). This study evaluates the incorporation of rCB in solid tyre tread compounds, focusing on its mechanical properties, reinforcing efficiency, and environmental benefits as a sustainable alternative to vCB.

2. METHODOLOGY

2.1. Materials and Characterization

Materials for this study were sourced from Sri Lanka's largest solid tyre manufacturing industry. Virgin carbon black (vCB, N330) served as a baseline for comparison, while recovered carbon black (rCB) from an Indian pyrolysis plant was evaluated in various formulations. The properties of rCB and vCB, obtained from supplier-provided Certificates of Analysis (COA), included inorganic content, pour density, oil absorption number (OAN), pellet hardness, and iodine adsorption number (IAN), as summarized in Table 1.

Table 1. Structural Properties of rCB and vCB

parameter	Units	rCB	vCB	Test Standard
Inorganic Content	%	17.42	0.37	ASTM D 1506
Pour Density	kg/ m3	484	376.99	ASTM D 1513
Oil Absorption Number	ml/100g	81.9	103	ASTM D 2414
Pellet Hardness	gf	32.27	27	ASTM D 5230 (vCB) ASTM D 3313 (rCB)
Iodine Adsorption Number	mg/g	NA	83.8	ASTM D 1510

Recovered carbon black (rCB) exhibits distinct differences from vCB, including higher inorganic content (17.42% vs. 0.37%), reflecting residual ash from the pyrolysis process (Dwivedi et al., 2020). Its lower oil absorption number (OAN, 81.9 vs. 103 ml/100g) indicates reduced surface activity, while higher pellet hardness (32.27 gf) enhances processing durability but may hinder uniform dispersion.

2.2. Formulation and preparation of composites

In this study, a series of rubber composites were formulated to assess the performance of recovered carbon black (rCB) in comparison with virgin carbon black (vCB). Five different formulations were prepared as shown in Table 2, a control formulation (R0) containing 100% vCB (N330) as the reinforcing filler, and four experimental formulations (R5, R10, R15, and R20), in which rCB was incrementally added at 5, 10, 15, and 20 phr, respectively, alongside the constant baseline of vCB. All other raw materials were kept constant across formulations to ensure comparability. An industrial scale Banbury mixer was employed for mixing and preparation of rubber compounds. After mixing, the compounds were sheeted out. Curing ingredients were added 24 h later in industrial scale kneader and warmed in two roll mill and molded vulcanizate sheets were prepared in two- day- light hydraulic press at 150 °C of vulcanization temperature.

Table 2. Formulation of Rubber Compounds

Ingredient	Compound No.				
	R0	R5	R10	R15	R20
Rubber	100	100	100	100	100
Reclaim Rubber	10	10	10	10	10
N330	51.4	51.4	51.4	51.4	51.4
rCB	0	5	10	15	20
Processing Oil	5.7	5.7	5.7	5.7	20
Chemicals	9.5	9.5	9.5	9.5	30

2.3. Cure characteristics

The curing characteristics of the rubber compounds were evaluated using an Oscillating Disc Rheometer (ODR) at 150°C. Parameters such as minimum torque (ML), maximum torque (MH), scorch time (ts2), and optimal curing time (tc90) were recorded. ML indicates the degree of mastication, while MH reflects the cross-linking density of fully vulcanized rubber. The tc90 represents the time required to achieve 90% of the cross-linking reaction, with an increase in torque signifying a higher cross-link density.

2.4. Structural properties

The Specific Gravity (SG) of the compounds were measured in a Wallace densimeter at 24 °C, in accordance with the ASTM D792 standard. The samples were first weighed in air ($m1$) and then immersed and weighed in distilled water ($m2$). The density of the distilled water ($\rho1$) was set to 1 g/cm3. The density of the composites was recorded.

2.5. Mechanical properties

The mechanical properties of rubber compounds with recovered carbon black (rCB) were evaluated following ASTM standards. Tensile strength and elongation at break were measured using a universal testing machine (ASTM D412) on dumbbell-shaped specimens at a 500 mm/min crosshead speed. Tear strength (ASTM D624) was assessed with crescent-shaped specimens, while the modulus at 300% elongation, indicating stiffness, was recorded during tensile tests. Shore A hardness (ASTM D2240) was measured with a durometer, and abrasion resistance (ASTM D5963) was determined using a DIN Abrader by recording weight loss. All tests were performed in triplicate to ensure accuracy.

3. RESULTS AND DISCUSSION

All characterized results are shown in Table 3. Maximum torque (MH), reflecting compound stiffness, showed minimal change at 5 and 10 phr rCB (R5, R10) but increased significantly at 15–20 phr (R15, R20) due to rCB's coarser particle size and lower surface area. Minimum torque (ML), indicating pre-vulcanization viscosity, remained stable at lower rCB levels but rose slightly at 20 phr, suggesting thicker compounds. Scorch time (ts2) and optimum cure time (tc90) decreased with higher rCB loadings, likely due to elevated volatile matter and ash content, which accelerated vulcanization.

The SG of the rubber compounds increased with the rising rCB loading. The performance of recovered carbon black (rCB) was evaluated against virgin carbon black (vCB, N330) using the control compound (R0) as a baseline. The key observations for mechanical properties of the tread compounds are discussed below.

Tear strength, which was the highest in the control compound (R0) decreased with the increase of rCB loading. At 5 and 10 phr, tear strength was slightly lower but acceptable for certain applications, while at 15 and 20 phr, it declined significantly due to weaker filler-polymer bonding caused by rCB's lower surface area.

The modulus at 300% elongation increased with rCB loading, with R20 showing the highest modulus. This reflects stiffer compounds, attributed to rCB's larger particle size and reduced surface activity, though excessive stiffness may compromise flexibility and durability. Tensile strength decreased with higher rCB loadings compared to the control (R0). At 5 and 10 phr rCB, tensile strength was comparable to R0, indicating partial substitution is feasible without significant performance loss. At 15 and 20 phr, tensile strength declined significantly due to increased ash content and weaker filler-polymer interactions in rCB, consistent with prior studies (Dwivedi et al., 2020; Zhong et al., 2019). At 5 and 10 phr, the reduction in elongation was moderate and within acceptable limits, suggesting minimal impact on flexibility. However, at 15 and 20 phr, elongation decreased significantly, reflecting the increased stiffness of the compounds due to higher rCB content, which limits their ability to stretch under stress. Hardness increased marginally with higher rCB loadings, indicating that the addition of rCB contributes to slightly stiffer compounds.

Abrasion resistance, a critical property for tyre treads, declined with increasing rCB content. At 5 and 10 phr, the abrasion loss values were comparable to the control compound (R0), indicating that rCB can match vCB performance for moderate wear resistance applications. However, at 15 and 20 phr, large particle size and ash content in rCB resulted in significantly higher abrasion loss, consistent with trends observed for tensile strength and tear strength.

Table 3. Characterized results of the compounds

Parameter	Units	Compound No.				
		R0	R1	R2	R3	R4
MH	d Nm	73.84	76.1	76.27	77.21	77.7
ML	d Nm	18.29	18.13	18.04	19.98	19.79
ts_2	Seconds	381	378	373	339	377
Tc_{90}	Seconds	848	842	837	747	807
SG	NA	1.12	1.14	1.14	1.15	1.15
Tear Strength	kg/ cm	68.15	58.89	59.28	55.75	52.85
Modulus @ 300%	Kg/ cm^2	100.5	115.35	108.5	127.5	130.67
Tensile Strength	Kg/ cm^2	183.88	188	193.26	190.05	175
EAB	%	478.34	481	491.66	426.67	398.34
Hardness	Shore A	66	66	67	71	73
Abrasion Loss	Mm^3	0.112	0.118	0.118	0.135	0.130

4. CONCLUSION

This study highlights the potential of using recovered carbon black (rCB) as a partial substitute for virgin carbon black (vCB) in solid tyre tread compounds. While rCB showed comparable mechanical properties to vCB at lower loadings (up to 10 phr), higher loadings reduced reinforcement efficiency due to higher inorganic content, lower oil absorption number (OAN), and lower surface activity. These results suggest that rCB can be a sustainable alternative in applications where ultra-high performance is not critical, contributing to a circular economy in the rubber industry. However, limitations remain in understanding rCB's reinforcing efficiency. Key factors like crosslink density and bound rubber, which influence rubber-filler interactions and vulcanization, were not evaluated in this study. Future research should address these factors and optimize pyrolysis and post-treatment processes, such as surface modification or ash removal, to enhance rCB's reinforcing potential.

Overall, rCB may serve as a viable and sustainable alternative to vCB, especially at lower loadings, reducing reliance on virgin materials and promoting sustainability by reusing pyrolysis-derived materials.

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DEVELOPMENT OF FIRE-RESISTANT BEHAVIOUR IN NATURAL RUBBER FOAM VULCANIZATES USING SUSTAINABLE MATERIALS

D. T. J. Jayawardhana[1]*, A. D. Weerakoon[2], and S. G. J. Perera[3]
[1,2,3]Institute of Technology University of Moratuwa, Sri Lanka
tharindujayawardana999@gmail.com[1]*, amalidhanu22@gmail.com[2], sudarshana79@gmail.com[3]

ABSTRACT: Fire safety is a critical consideration in foam-based applications, especially with the increasing demand for sustainable, non-toxic materials. This research explores the development of fire-resistant natural rubber foam by incorporating eco-friendly, sustainable materials. The study focuses on enhancing fire resistance while maintaining the foam's mechanical integrity and environmental compatibility. In preliminary experiments, varying concentrations of natural additives were integrated into natural rubber foam to assess their effect on fire resistance. Eggshell powder was identified as particularly effective, with optimised concentrations forming a protective tar layer that slows fire propagation. Further testing demonstrated that samples containing less than 20 parts per hundred rubber (pphr) of eggshell powder achieved optimal fire resistance, offering an effective barrier against ignition. In contrast, concentrations exceeding this threshold showed diminished efficacy due to material accumulation, highlighting the importance of optimal additive loading. This study's findings offer a promising approach for producing safer, more sustainable foam materials, with applications across industries where fire risk is a concern. By replacing conventional flame retardants with bio-based alternatives, this research presents an innovative pathway for enhancing fire safety while supporting green manufacturing. The implications for product safety, environmental sustainability, and cost-effectiveness position this work as a valuable contribution to the advancement of fire-resistant materials.

Keywords: eco-friendly innovation, fire resistance, fire safety, natural rubber foam, sustainable material

1. INTRODUCTION

Natural rubber is highly valued for its elasticity, resilience, and eco-friendly properties, which make it indispensable across industries. However, its flammability presents significant safety risks, especially in contexts where fire hazards are prevalent. Traditionally, chemical flame retardants have mitigated these risks, but they raise environmental and health concerns due to their toxicity and persistence in the environment (Pristine, 2024). As industries shift toward sustainable manufacturing, there is an increased demand for natural, non-toxic alternatives that enhance fire resistance without compromising ecological benefits (Matmake, 2024).

This study explores the potential of bio-based materials, specifically eggshell powder and rice husk silica, to improve fire resistance in natural rubber foam. Derived from agricultural waste, these materials offer promising advantages due to their availability, low cost, and inherent thermal resistance properties as shown in prior studies (Chana Prapruddivongs, 2020) . By analyzing the effects of these materials at different loadings, this research aims to develop an optimized natural rubber foam formulation with enhanced fire resistance, contributing to both product safety and environmental sustainability.

2. METHODOLOGY
2.1 Sample Preparation
Foam samples were prepared using eggshell powder and rice husk silica as fillers and also without any filler (Fig.1 & 2). The filler loadings varied from 1 to 10 parts per hundred rubber (pphr) for both fillers.

Fig. 1. Eggshell Powder added samples

Fig. 2. Rice Husk Silica added samples

2.2 Fire Propagation Testing

To evaluate the fire resistance properties of the natural rubber foam vulcanizates, testing was conducted following the ASTM E1353 standard, specifically for cigarette ignition resistance. This involved placing a smoldering cigarette on the test samples under controlled airflow conditions. According to the standard, to pass the test, any resulting char length must not exceed 2 inches (5.1 cm) from the original ignition point. (E1353)n our tests, the samples containing eggshell powder demonstrated successful performance by self-extinguishing without reaching or exceeding the specified char length, thus meeting the ASTM E1353 criteria. This was further validated through additional fire propagation tests, where 4-inch long, 1 cm² cross-sectional strips of each filler-loaded and control sample were created. The propagation time of fire along these strips confirmed that the eggshell powder-loaded samples exhibited the slowest fire spread, reinforcing their flame-retardant properties.

2.3 Further Experimentation

Based on initial results indicating fire resistance in eggshell powder-added samples, the research shifted focus to increasing the eggshell powder loading up to 25 pphr. No further experiments were conducted with rice husk silica at this stage. Observations noted the accumulation of eggshell powder at the bottom of samples with loadings above 20 pphr.

2.4 Testing of Optimized Samples

Fire tests were then conducted on the optimized samples with eggshell powder loadings below 20 pphr, as these were determined to be the most effective based on previous results. Significant findings included the formation of a protective tar layer in these samples, which effectively halted fire propagation.

3. RESULTS AND DISCUSSION

Egg shell and rice husk incorporated foam samples (Fig 3) exhibits difference in propagation time for ignition due to structural difference in two materials.
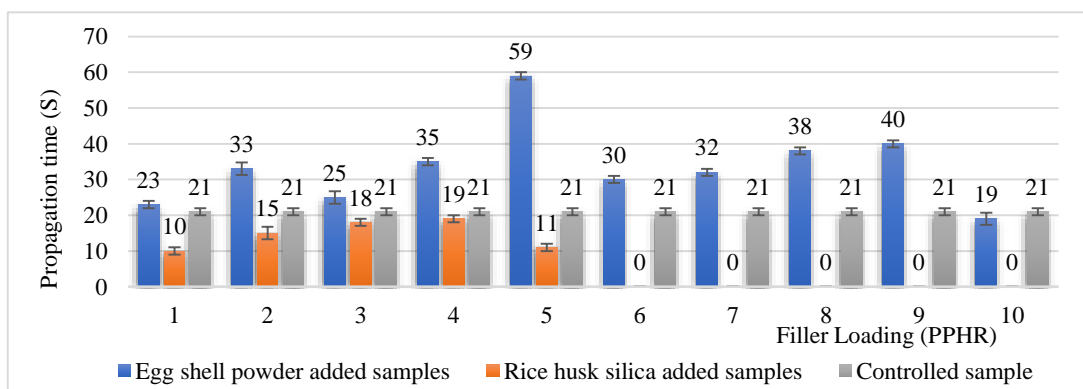
Fig. 3. Propagation time for ignition of eggshell and rice husk added foam rubber samples

The samples containing eggshell powder exhibited significantly better fire resistance than those with rice husk silica. This finding highlighted the effectiveness of eggshell powder as a natural flame retardant

The increase in eggshell powder loading beyond 10 pphr led to further improvements in fire resistance. The formation of a protective tar layer (Fig 4) was observed in samples with loadings below 20 pphr, which acted as a barrier to fire propagation

Fig. 4. Formation of a Protective Tar Layer

The accumulation of eggshell powder at higher loadings (above 20 pphr) suggests a potential limit to its effective incorporation in the foam matrix. This accumulation may hinder uniform distribution, which is crucial for optimizing fire resistance.

The findings emphasize the potential application of eggshell powder in the mattress and foam-related industries, offering a sustainable and effective solution for enhancing fire safety. The use of natural materials not only improves product safety but also reduces environmental impact, making it a viable alternative to conventional flame retardants.

4. CONCLUSION

This study demonstrates the successful enhancement of fire resistance in natural rubber foam vulcanizates through the incorporation of sustainable fillers, specifically eggshell powder. Experimental results revealed that samples containing eggshell powder exhibited significantly better fire resistance than those with rice husk silica, highlighting the superior effectiveness of eggshell powder as a natural flame retardant. A key discovery was that increasing the eggshell powder loading up to 25 parts per hundred rubber (pphr) led to the formation of a protective tar layer. This layer acted as a physical barrier, effectively halting fire propagation in samples with loadings below 20 pphr. The presence of calcium carbonate ($CaCO_3$) in eggshell powder plays a pivotal role in enhancing fire retardancy. Upon heating, calcium carbonate decomposes to release carbon dioxide (CO_2) gas, which cools the material and dilutes combustible gases, thereby reducing the risk of ignition. The residue left after decomposition further aids in creating an insulating barrier that limits heat transfer and sustains the structural integrity of the foam under high temperatures (Pondelak, 2021).

These findings underscore the potential of eggshell powder as a sustainable, cost-effective flame retardant, offering a viable alternative to conventional, chemical-based retardants. This innovation not only enhances the safety profile of rubber foam products but also aligns with the industry's shift toward eco-friendly manufacturing processes. By incorporating eggshell powder as a natural flame retardant, this research provides valuable insights into sustainable material design, contributing to safer and greener solutions for the mattress and foam industries.

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ENHANCING RENEWABLE ENERGY CAPACITY THROUGH PUMPED STORAGE SYSTEMS: A CASE STUDY

H. M. H. N. Bandaranayake[1], T. Bambaravanage[2*], K. G. C. J. Senarathna[3], D .N. Thalagala[4], L. U. Bhagya[5], and H. M. C. L. Bandara[6]

[1, 2, 3, 4, 5, 6] Institute of Technology University of Moratuwa, Sri Lanka

21ee0257@itum.mrt.ac.lk[1], tharangikab@itum.mrt.ac.lk [2*], 21ee0331@itum.mrt.ac.lk[3], 21ee0337@itum.mrt.ac.lk[4], 21ee0258@itum.mrt.ac.lk[5], 21ee0256@itum.mrt.ac.lk[6]

ABSTRACT: Sri Lanka aims at achieving 70% of its power generation from renewable energy sources by 2030 to meet its electricity demand. To this end, various approaches are being explored to generate electricity with minimal or no emissions. Among these, wind and solar photovoltaic (PV) energy are becoming increasingly popular. Due to their intermittent and non-dispatchable nature, it is crucial to utilize harnessed energy whenever it is available. A Pumped-Storage System (PSS) is an effective solution for storing excess energy in the national grid. This approach helps meet peak demand with cost-effective electricity, generated from more environmentally friendly technologies. An extensive survey was conducted to identify a suitable location, referencing a 1: 10,000 map of Sri Lanka, research papers, and technological reports. The researchers propose a PSS with a capacity of 2 MW based on the Maussakele Reservoir which plays a pivotal role in Sri Lanka's hydropower generation. The upper pond for the PSS is a natural pool situated in Laxapana tea plantation. The natural elevation difference between the two reservoirs enhances the energy storage capacity. Excess energy from the national grid during off-peak hours will be stored as potential energy and subsequently converted into hydroelectricity during peak hours. The effectiveness of the proposed scheme has been validated through mathematical analysis. Accordingly, the annual expected electricity generation of 1,460 MWh would result in saving of over LKR hundred million under the current economic scenario of Sri Lanka positively to the national economy. Furthermore, the proposed PSS is designed to minimize the impact on ecosystems, habitats, and the environment,

Keywords: generation, hydropower, pump storage, renewable energy

1. INTRODUCTION

Globally, nations are exploring alternative energy sources as alternatives to conventional fossil fuel aiming to reduce their reliance on conventional fossil fuel. Various eco-friendly energy solutions are needed to address key climate change issues effectively. Sri Lanka has set a target of achieving 70% renewable energy (RE) goal by 2030. Though it is a challenging target, we all should strive collectively to reach it to minimize the carbon footprint. The growing demand for renewable energy sources has led to increased interest in energy storage solutions to avoid energy curtailment. PSS has emerged as a promising technology to enhance renewable energy capacity and grid stability (Ceylon Electricity Board, 2023; Katsaprakakis et al., 2012; Kose et al., 2020; Penagos-Vásquez & Sanin-Villa, 2021; PUCSL, 2024).

According to Singh et al. (2017), the forecasted daily demand-supply scenario in 2030 is demonstrated in Fig.1. The excess generation of electricity during daytime could be utilized to address peak demand through energy storage. PSS and battery storage are two prominent methods for energy storage in power generation. Due to cost-effective capability for large

Fig.1. Hypothetical daily load curve of Sri Lanka in 2030

energy storage over extended periods, longer life span, lower environmental impact, the PSS remains

a reliable and efficient option and thus becomes an increasingly attractive choice (Dilrukshi et al., 2018).

This research paper examines the effectiveness of PSS in improving renewable energy integration using the *Mauassakele PSS* hydroelectric project as a case study. This approach helps meet peak demand with cost-effective electricity generated through more environmentally friendly technologies (Rehman et al., 2015). The researchers propose a Pumped-Storage System (PSS) with a capacity of 2 MW with its upper reservoir being a natural pool situated in the Laxapana tea plantation near the west bank of the Maussakele Reservoir. This pool is replenished by two natural rivulets. This will be a promising solution for Sri Lanka's pursuit of future energy security and economic growth.

2. METHODOLOGY

The selection criteria for the proposed Pumped-Storage System (PSS) location considers several critical factors. The chosen site for the upper reservoir must be capable of retaining sufficient water and providing a high head to generate the expected power output. Additionally, the construction of the reservoir, powerhouse, and related infrastructure should minimize environmental and ecological impacts. Other key considerations include the availability of adequate rainfall and a substantial catchment area (Kabo-Bah et al., 2023).

The proposed location for the 'Maussakele PSS' is in the south-central mountainous region of Sri Lanka, within the Nuwara Eliya District. It is situated northwest of the Maussakele Reservoir, in Laxapana tea estate, at an altitude ranging from approximately 6,000 to 7,000 feet. A 1:10,000-scale map of Sri Lanka was used to determine the location and distances between the selected sites. Real-time data were also analyzed to evaluate site suitability, focusing on factors such as soil conditions, average rainfall, population density, and land use, including farming activities.

The upper reservoir (UR) is an existing natural pond covering approximately 5,830 m², located in a well-developed tea plantation area with a relatively low population density. The lower reservoir (LR) is the Maussakele Reservoir, which has sparse vegetation and is similarly less populated. The UR lies within the Maussakele catchment area, characterized by numerous small waterways, while the LR is an existing water tank built on the Maskeliya *Oya* to support the Wimala Surendra Power Plant.

The basic design of the PSS is shown in Fig. 2, with the Maussakele Reservoir serving as the lower reservoir and the natural pond in Laxapana tea estate acting as the upper reservoir. The elevation profile has been analyzed to confirm the feasibility and energy storage capacity of the system (Fig.3).
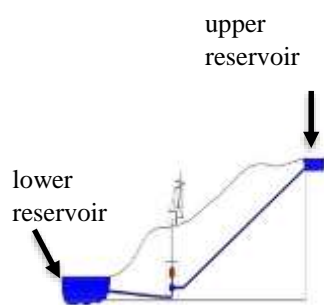
Fig. 2. The basic design of the PSS

Fig. 3. Elevation profile of LR and UR

It was proposed to perform design calculations for a 2 MW pumped-storage plant. This capacity can be increased by enhancing the depth of the upper reservoir (UR). The PSS is intended to operate during the nighttime peak demand period, which typically lasts for approximately two hours, from 7:00 PM to 9:00 PM. Table 1 shows the results obtained and the respective equations used in the process of obtaining the annual energy generation of the proposed 2MW PSS.

Table 1. The results obtained and the respective equations used in calculations

Equation used	Value/ values obtained
$Q_{max} = P/\eta \rho g H_e$	Maximum plant discharge (apparent) = 2.05m^{3}s^{-1}
$V_e = Q_{max} \times T \times 3600 m^3$	Required capacity of upper reservoir= 14760m^2
$V_s = q_s$ x Ca x 100	Calculated sedimentation vol. of LR = 235,431m^3 Calculated sedimentation vol. of UR = 836.28m^3 Calculated sedimentation level of LR = 1,142m Calculated sedimentation level of UR = 1,286.5m
$Q_{max} = (\pi \times D^2/4) \times 5\ m/s$	Inner dia. (D) of the headrace tunnel = 0.72m Low water level of LR (LWL(L)) = 1143.44m Low water level of UR (LWL(U)) = 1287.94m High water level of UR (HWL(U)) = 1296.36m High water level of LR (HWL(L)) = 1143.44m
RH of UR = HWL(U) -1/3(HWL(U) -WL(U))	RH of UR = 1293.56m
Head loss = *GHx5%*	Head loss = 7.5m Effective head = 142.62
$Q_{max} = P/\eta \rho g H_e$	Actual plant discharge = 1.68 m^3/s^{-1}
E = PT	Annual energy generation = 1460MWh (assume night peak occurs for 2h)

Where,

Expected Power Generation, P = 2MW

LR volume = 133.3x10^{6}m^3

Head between UR and LR = 130m

Effect. head bet.^{n} UR and LR = 130x0.9 = 117m

Peak duration of the PS, T = 2h

Available drawdown (h$_a$) = 8.42m

Rated head (RH) of LR = 1143.44

Gross head (GH) = 150.12m
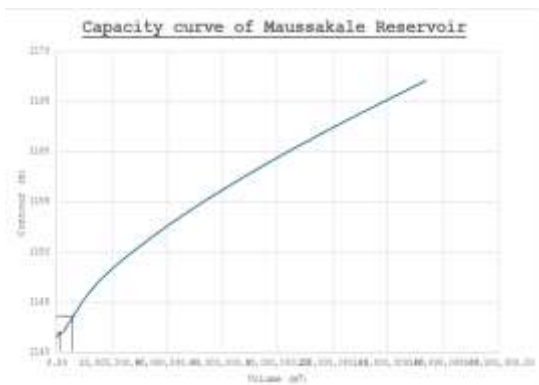
Fig. 4. Capacity curve of LR (Maussakele)
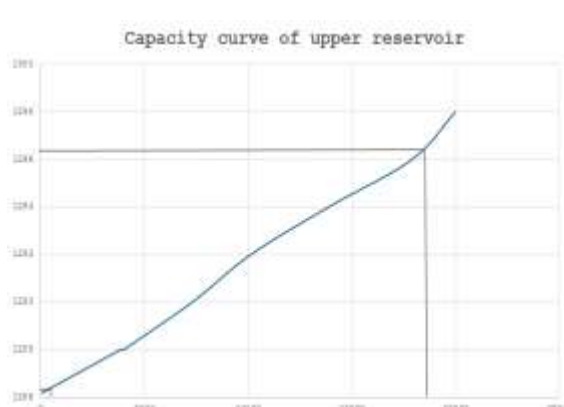
Fig. 5. Capacity curve of UR

Calculation of annual saving on cost of generation:

If we assume the average unit cost of electricity generation based on naphtha and PSS are 80/- LKR and 8.50 LKR respectively, by running the PSS during peak hours (i.e. from 7.00 to 9.00PM) for 2h,

Amount of foreign exchange saving= 1460x103 x (80.00-8.50) = 104.39 x 106LKR

According to Economic and Social Statistics-2024, (CBSL, 2024), the annual electricity generation based on fuel oil (FO) in Sri Lanka is 3135GWh (1975GWh from CEB and 1160GWh from private sector). A considerable amount of this FO is utilized to meet the night peak demand   (Singh et al., 2017). So, by running the PSS during peak demand hours, it is possible to save 104.39x106 LKR directly.

3.   RESULTS AND DISCUSSION

It is possible to generate 1460MWh with the proposed PSS which has a generation capacity of 2MW.The rated heads of the upper reservoir (UR) and lower reservoir (LR) are 1,293.6 m and 1,143.4 m, respectively, with an effective head of 142.6 m.

This would result in significant saving for the country as the peak demand is usually addressed by thermal power plants. The current average unit cost of thermal power generation is around 80 LKR. If this proposed PSS could be brought to reality, it could directly save LKR 104.39 million foreign exchange. This saving would have a considerable positive impact on the country 's economy and GDP.

Since the UR is an existing pond in Laxapana tea plantation, constructing the PSS, would involve a minimal environmental impact. Additionally, the potential relocation of communities, if needed, would be less challenging, as the population density is low and mostly comprised of tea plantation residents. Other benefits include reduced construction costs, minimal disruption to local water tables, and an overall more sustainable approach.

Further, the capacity of the power plant can be increased by deepening the UR, leading to additional savings on FO.

4.   CONCLUSION

The results show the benefits that can be achieved through pumped storage power generation. Hence, the proposed methodology based on PSS is a viable and effective solution to enhance the renewable energy capacity of Sri Lanka. It promises substantial savings of over hundreds of millions of rupees, with a positive impact on the national GDP, while causing minimal disruption to the ecosystem and natural habitats.

This research study is still in progress. A key part of the study involves collecting technical data, such as collecting technical information such as the number of affected families, the number of trees to be removed, the extent of tea plantations impacted, and the availability of relocation facilities that would not disrupt the affected individuals' lifestyles. Sufficient funds and time constraints are some limitations for collecting data. This data would be incorporated in more accurately assessing the actual savings and benefits of the proposed PSS.

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GEOTHERMAL ENERGY RESOURCES FOR ELECTRICITY GENERATION IN SRI LANKA: A CRITICAL REVIEW OF CURRENT STATUS AND PROSPECTS

D. L. S. Hansanie[1] and T. Bambaravanage[2*]
[1] General Sir John Kotelawala Defence University, Sri Lanka
[2] Institute of Technology University of Moratuwa, Sri Lanka
hansanie.dls@kdu.ac.lk[1]; tharangikab@itum.mrt.ac.lk[2*]

ABSTRACT: Sustainable development faces critical challenges including rapid population growth, energy shortages, and rising environmental pollution. With global electricity generation anticipated to triple by 2035, geothermal energy emerges as a notable solution due to its abundance, low CO2 emissions, and stability. Despite geothermal energy accounting for approximately 0.3% of global power generation and 1.5 of renewable power, it remains underutilized compared to other renewable sources. The United States and China are leaders in geothermal applications having made significant advancements in recent years. This review paper examines the potential of geothermal energy for Sri Lanka, a nation grappling with increasing energy demands and environmental concerns. Through an analysis of 25 research papers and technical reports, this study evaluates various geothermal power generation methodologies and assesses the suitability of Sri Lanka's geothermal resources. The findings highlight the feasibility of different geothermal technologies, taking into account local temperature profiles and geographical distribution. The review also addresses environmental impacts, challenges, and the potential benefits of geothermal energy for Sri Lanka, advocating for its development as a viable, low-carbon alternative to fossil fuels.

Keywords: geothermal energy, geothermal resources, Sri Lanka, hot springs, renewable energy

1. INTRODUCTION

To mitigate the severe consequences of climate change, it is essential to limit global temperature rise to 1.5°C above pre-industrial levels. Currently, the Earth's temperature has risen by approximately 1.1°C compared to the late 19th century, with emissions still increasing. National strategies predict a 9% rise in global greenhouse gas emissions by 2030 compared to 2010 levels. Achieving the Paris Agreement's goal requires a 45% reduction in emissions by 2030 and net-zero emissions by 2050 (Arnórsson, 2004).

Geothermal energy has seen significant advancements, with an additional 1 GW of capacity projected annually over the next six to seven years. The World Bank's Energy Sector Management Assistance Program has allocated $235 million through the Clean Technology Fund to expand geothermal energy under its Global Geothermal Development Plan (Zhu, 2020). Despite extensive research, reviews addressing geothermal energy's potential for electricity generation in developing countries like Sri Lanka remain scarce. This review evaluates Sri Lanka's geothermal resources and potential, addressing challenges and opportunities to support energy diversification and security.

Geothermal energy stands out among renewables for its stability, abundance, and carbon-neutral profile. It currently contributes 0.3% to global electricity and 1.5% to renewable energy production (Rybach, 2003; Arnórsson, 2004). Derived from the Earth's internal heat via hydrothermal reservoirs or enhanced geothermal systems, its technology is well-established (Arnórsson, 2004). Globally, renewable electricity is expected to triple from 2010 to 2035, reaching 31% of total production (Zhu, 2015). Currently, 82 countries use geothermal energy directly (Fig. 1), while 26 generate electricity, with a total installed capacity of 16,318 MW across 198 fields (Niknam, 2020). The U.S. leads in geothermal power production, contributing 28.8% of global capacity, while China leads in direct utilization, holding 25.2% of the global share (Montenegro, 2016; Zhu, 2020).
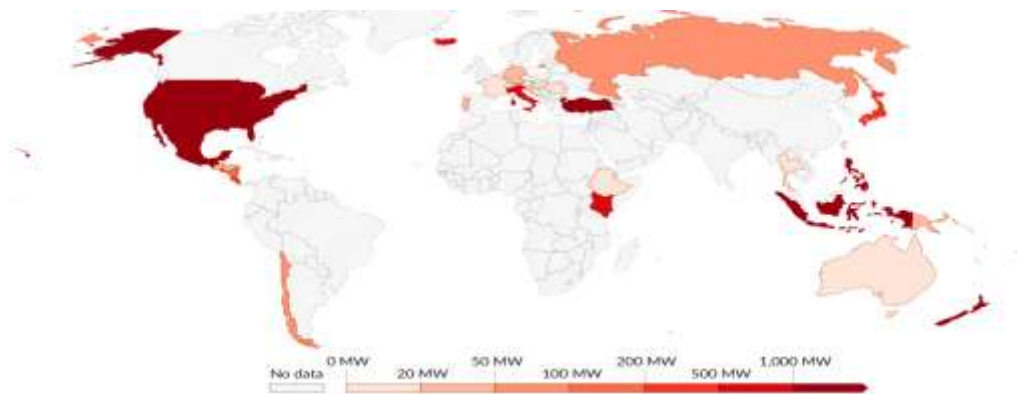
Fig. 1. Installed Capacity of Geothermal Power Generation in the World

2. METHODOLOGY

This review is based on an extensive literature survey of approximately 25 research papers and technical reports on geothermal energy. The search for relevant literature was conducted using databases such as Google Scholar, IEEE Xplore, and ScienceDirect. The primary keywords used in the search included: geothermal energy, geothermal power generation, geothermal resources in Sri Lanka, renewable energy technologies, geothermal plant efficiency, and sustainable energy systems. The reviewed papers span a publication range from 1995 to 2023, with the majority of them published in prominent journals focused on renewable energy, geothermal research, and power systems. The analysis considered both established global methodologies and emerging technologies for harnessing geothermal energy, particularly those applicable to regions with similar geological conditions to Sri Lanka.

The analysis also included Sri Lanka-specific studies, focusing on the temperature profiles and geographical distribution of potential geothermal resources. This allowed for an evaluation of the most suitable power generation methods for the country.

3. RESULTS

3.1 Methodologies Available Globally for Geothermal Power Generation

Geothermal energy is harnessed using various technologies, each suited to different geological conditions. Dry Steam Power Plants use steam from underground reservoirs to drive turbines, a simple and early technology limited to areas with high-temperature steam. Flash Steam Power Plants, the most common, release high-pressure hot water into low-pressure tanks, causing it to flash into steam that drives turbines. Binary Cycle Power Plants utilize lower temperature resources, where geothermal water heats a secondary fluid with a lower boiling point, making it viable in more diverse locations.

Enhanced Geothermal Systems (EGS) artificially increase rock permeability, allowing water to be heated in areas without natural hydrothermal resources. Hydrothermal Convection Systems use naturally occurring hot water or steam but are geographically limited. Lastly, Ground Source Heat Pumps (GSHPs), primarily used for heating and cooling rather than power generation, exploit the stable ground temperature for energy-efficient building systems. Each technology reflects the adaptability of geothermal energy, offering unique solutions based on resource availability and technological capability, with potential relevance to Sri Lanka's energy landscape.

3.2 Distribution of Geothermal Resources in Sri Lanka

Sri Lanka possesses considerable geothermal resources, though their distribution is uneven across the country. Geothermal resource assessments indicate significant potential, particularly in regions with high geothermal activity. Understanding this distribution requires examining Sri Lanka's geological framework, particularly its Proterozoic crustal units.

With reference to Fig. 2, the Proterozoic basement consists of three distinct crustal units: the Highland Complex (HC), with Neodymium (Nd) model ages ranging from 2.0 to 3.4 Ga, the Wanni Complex (WC), and the Vijayan Complex (VC), both dated between 1.1 and 1.8 Ga (Mathvan and Fernando, 2001). The 350 km thermal spring line at the tectonic contact between the HC and the eastern VC marks a significant area of high heat, with tectonic movements along deep-seated lineaments likely causing heat generation through exothermic reactions during serpentinization (Dissanayake and Jayasena, 1998).

Fig. 2. Simplified Geological Map of Sri Lanka Showing the Proterozoic Crustal Units (Mathvan and Fernando, 2001)

The upward movement of magmatic fluids and mixing of crustal and mantle materials along the tectonic boundary has also contributed to the formation of heat-producing granites, which are associated with high concentrations of uranium, further adding to the geothermal system's heat balance. Despite this potential, Sri Lanka's geothermal resources remain largely underutilized, with most thermal springs used primarily for recreation. These geothermal manifestations, identified through ten low-enthalpy thermal springs with temperatures ranging from 35°C to 61°C, are located along a narrow belt parallel to the lithological boundary between the Highland Complex (HC) and the Vijayan Complex (VC) (Kumara, 2014).

A preliminary survey identified several significant hot spring sites, such as Kapurulla, which records the highest temperature, and others including Mahapelessa in Hambantota, Kanniya in Trincomalee, and Rangiriulpotha in Gomarankadawala. Some springs, like Mahapelessa and Rangiriulpotha, feature single wells in marshy environments with unique vegetation, while others, such as Kapurulla, display significant temperature variations over short distances (Samaranayake, 2021). The temperature variations of these springs, summarized in Table 1, highlight the diverse thermal characteristics of Sri Lanka's geothermal resources. The presence of medium- to low-temperature resources suggests that binary cycle power plants could be particularly suitable for the country. Binary cycle plants operate efficiently at lower temperatures (85°C–180°C), making them ideal for Sri Lanka's geothermal profile. In contrast, dry steam plants require resources over 235°C, and flash steam plants are effective at temperatures between 180°C and 235°C (Zarrouk & Moon, 2014).

Sri Lanka's geothermal resources fall within the medium to low-temperature range, making binary cycle technology the most suitable option for efficient power generation. Binary cycle plants operate at temperatures between 85°C and 180°C, achieving efficiencies of 10% to 13%. In contrast, dry steam plants, requiring temperatures over 235°C, can reach efficiencies of up to 20%, while flash steam plants, effective at 180°C to 235°C, offer efficiencies of 10% to 17% (Zarrouk & Moon, 2014). Considering the country's geothermal profile, the binary cycle method provides the best balance of efficiency and operational feasibility.

Table 1. Average Temperature of Thermal Springs in Sri Lanka. (Samaranayake, 2021)

	Hot Spring	Average Temperature (^{0}C)
	Rangiriulpotha	39
	Kanniya	42-44
	Nelumwewa	55-62
	Kapurella	73.5
	Mahaoya	47-54
	Wahawa	44-48
	Mahapeless	46

4. DISCUSSION

Challenges and Barriers to Geothermal Development in Sri Lanka

Globally, geothermal prospects are typically associated with magmatic geological settings, where substantial development knowledge exists. In contrast, geothermal prospects in metamorphic terrains, such as those in Sri Lanka, remain largely experimental. The country's geology, dominated by ancient Proterozoic metamorphic rocks, shows minimal thermal signatures apart from sporadic hot spring occurrences, complicating the identification of heat sources for these springs (Samaranayake, 2021). Assessing geothermal prospects requires characterizing the heat source, geothermal gradients, and temperature levels; however, Sri Lanka lacks the expertise and equipment necessary for such integrated surveys, necessitating external support (Samaranayake, 2021). While solar and wind energy development progresses, geothermal energy remains underexplored due to limited initiatives from the government and private sectors. Unlocking geothermal potential could attract investments, but identifying and characterizing viable sources remains a primary challenge.

Despite its technical potential, several barriers hinder large-scale geothermal development in Sri Lanka. The absence of comprehensive data on the location and characteristics of deep geothermal resources poses a critical challenge (Abewickrama, 2022). Additionally, accessing promising sites, often in remote or difficult-to-reach regions, complicates exploration efforts. Existing geothermal reservoirs that might support electricity generation are deemed economically unviable due to high upfront costs and uncertainties regarding resource depth and quality deterring investors (Abewickrama, 2022).

5. CONCLUSION

This review paper provides a comprehensive analysis of geothermal energy, its potential applications, and its suitability for Sri Lanka. By examining 25 research papers, we evaluated various geothermal methods and their applicability to the local context, including temperature profiles and geographic locations conducive to power generation. The findings underscore geothermal energy's potential as a sustainable solution to the country's energy needs, emphasizing the importance of addressing environmental impacts and operational challenges. With best practices and innovative solutions, geothermal energy can significantly contribute to Sri Lanka's energy security and environmental goals.

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BISPHENOL-A BASED SHAPE MEMORY POLYMER FOR SOFT ROBOTIC GRIPPER APPLICATIONS

S. Jayalath[1], M. Herath[2], J. Epaarachchi[3] and S. Patel[4]

[1,2,3,4]Univeristy of Southern Queensland, Australia,

[1]Instituteof Technology University of Moratuwa, Sri Lanka,

[2]University of Hull, United Kingdom

Sandaruwan.Jayalath@unisq.edu.au[1*], m.herath@hull.ac.lk[2], Jayantha.epaarachchi@unisq.edu.au[3], Shiwam231994@gmail.com[4]

ABSTRACT: Shape Memory Polymers (SMPs) are considered smart materials due to the continuous development of their applications in space, aerospace, construction, and biomedical fields. SMPs can be fabricated like other polymers, taking different complex shapes and having the ability to program them into another shape. This ability has made them ideal candidates, especially in soft robotics. This research develops a soft robotic gripper using an actuator made with epoxy-based SMP that can be fully activated using heat at 135.7°C. The SMP for the gripper mechanism was designed using Bisphenol-A based epoxy and m-Xylylenediamine. It was observed that the SMP gripping mechanism could apply a maximum force of 5 N to grip a spherical object adequately. These SMP actuators can be further enhanced to develop soft robotic devices that facilitate a wider range of engineering and biomedical applications such as invasive medical surgeries, nano-electromechanical systems (NEMS) and micro-electromechanical systems (MEMS) manufacturing.

Keywords: force sensitive resistor, shape memory polymer, soft robotic actuator, thermomechanical characteristics

1. INTRODUCTION

Shape memory polymers (SMPs) are a class of active, deformable material that can switch between a temporary shape, which can be freely designed, and the original shape (Mu et al., 2018). SMPs can be categorized as smart material due to their capability of deforming and holding a temporary shape and recovering to the original shape in response to external stimuli, such as temperature, light and magnetism (Jeewantha et al., 2022). This property can be applied to many potential and promising engineering applications in a wide range, including structural, biomedical, space and aerospace engineering. For example, light-activated SMP can be used in specific areas of the applications mentioned above since they can be activated remotely by sending light through optical fibres (Herath, et al., 2020).

The term Soft Robotics has come to light with the recent developments of smart materials. The word Soft Robotics is recently defined as "continuum robots made of soft materials that undergo continuous elastic deformation and produce motion through the generation of a smooth backbone curve" (Laschi et al., 2016). Most of the soft robotic designs are inspired by nature. The traditional actuators usually comprise large and complex structures to achieve their desired movements. This limits their use in smaller-scale applications (Shen et al., 2016). SMPs are a promising solution to break these limitations. Furthermore, imitating complex human body parts such as muscles and joints of hand movements needs to be developed by overcoming the boundaries remaining in conventional robotic technologies (Herath, et al., 2018).

The aim of this study is to manufacture a Bisphenol-A Epoxy based SMP to develop a soft actuator gripper. The actuator was designed to mimic the behaviour of a human finger. The human finger consists of three major joints: metacarpophalangeal (MCP) joint, proximal interphalangeal (PIP) joint and distal interphalangeal (DIP) joint (Yang et al., 2016)This research is focused on the behaviour of the DIP joint, which is simply the topmost joint of the index finger. Its significance is

the usage of lightweight material and a simpler design without moving parts. The proposed design consists of simpler and more improvable SMP material that can be further developed.

2. MATERIALS AND METHODS

2.1 Synthesis of SMP and Fabrication of the Finger

A precise mixture of materials was used to synthesise the epoxy-based SMP. The ratio of epoxy resin to hardener was 5:1. Bisphenol-A diglycidyl ether (BADGE) and m-Xylylenediamine (m-XDA) were used as the epoxy resin and the hardener, respectively. These materials were supplied by Sigma Aldrich Australia.

The dual curing method, which includes a post-curing cycle, proposed by (Dlugaj et al., 2024) was employed to speed up the curing process and minimise energy usage. The curing cycle consisted of four stages. The first stage was the degasification process to remove air bubbles in a vacuum oven at room temperature. Then, the mixture was poured into two types of moulds. One is to make flat sheets for the DMA test specimens. The SMP fingers were cast by using an Aluminium mould. The next three stages of the cycle were done in the curing oven. SMP was cured in the oven at 60°C for 2 hrs, 100°C for 3 hrs, 140°C for 1 hrs and finally at room temperature for 24 hours.

An Aluminium mould with a 10 mm thickness, 10 mm depth, and a 136° gripper angle was used to cast SMP fingers. To increase their durability, a Teflon coating was sprayed on the fingers. The SMP fingers were kept under pressure and heated until they achieved a 146° angle during the SMP programming stage.

2.2 Computer-aided Design of the Gripper

The CREO 6.0 commercial software package was used to design the base and actuator/ finger assembly of the gripper, as shown in Figure 1 (a). The base of the gripper assembly and the rigid fingers shown in figure 1(b) were fabricated using Polylactic Acid (PLA) via the 3D printing rapid prototyping method. Then, one of the moulded and programmed SMP fingers and two 3D-printed rigid fingers were assembled according to the 3D model of the gripper.

2.3 Measuring the Force Generated

Once the assembly was completed, a camera was set up to observe and video record the shape-recovering process. A plastic ball was placed in the middle of the gripper assembly. Haptic sensors (Force Sensitive Resistors, FSR) were attached to each finger before the gripping process was performed(Shaikh et al., 2015). An Arduino Uno microcontroller board was programmed for the haptic sensors to improve the force readings generated by finger movement.

2.4 Characterisation of SMP Material

The DMA and DSC techniques were used to observe the behaviour of the SMP material. A DMA test was performed to determine the primary glass transition temperature (T_g) value and the influence of temperature on the storage modulus and loss modulus. The DMA test was conducted using TA Instruments, a dynamic mechanical analyser (DMA Q800). To measure the secondary T_g values of the SMP, a TA instruments DSC-25 was used. The shape recovering process was observed visually. These tests were primarily performed to gather data that can be used for the future development of the SMP finger. Furthermore, the morphology of the developed SMP was observed using Olympus DSX5000 microscope and JCM-600 Scanning Electron Microscope (SEM).
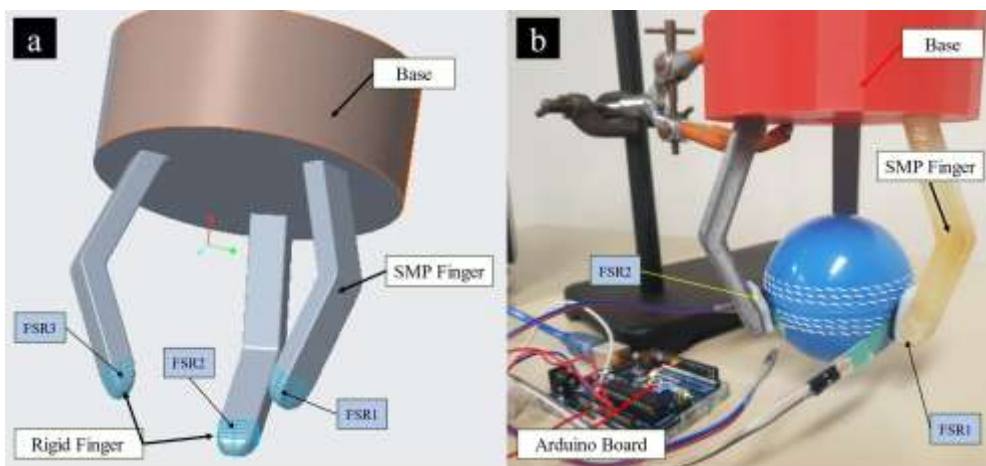
Fig. 1. (a) 3D gripper Assembly model and (b) Actual gripper assembly.

3. RESULTS AND DISCUSSION

3.1 Properties and Morphology of SMP

At temperature exceeding the glass transition temperature (T_g), an SMP material can be programmed into a desired shape by applying an external force. Then, the shape is then held until it is fixed, and the material is cooled down transforming it to a frozen polymer at a low temperature. Subsequently, when the temperature is raised above T_g, the shape recovers to its original shape (Jayalath et al., 2024). Therefore, measuring different T_g values using multiple methods is essential. The T_g helps determine the temperature where the SMP changes phase from glass to rubber. A DMA test was performed to observe the influence of temperature on the Viscoelastic behaviour of the SMP. The DMA graph showed storage onset temperature (T_s) at 120.57°C and the peak temperature (T_δ) of Tan(δ) at 135.7°C as shown in Fig. 2(a). The T_s temperature was considered the primary Tg value where the SMP starts recovering and losing its thermomechanical properties. The T_δ temperature was considered the temperature for shape programming. Furthermore, secondary T_g values where the SMP change its phases were calculated using the midpoint half-height value of the DSC curve, as shown in Fig. 2(b).
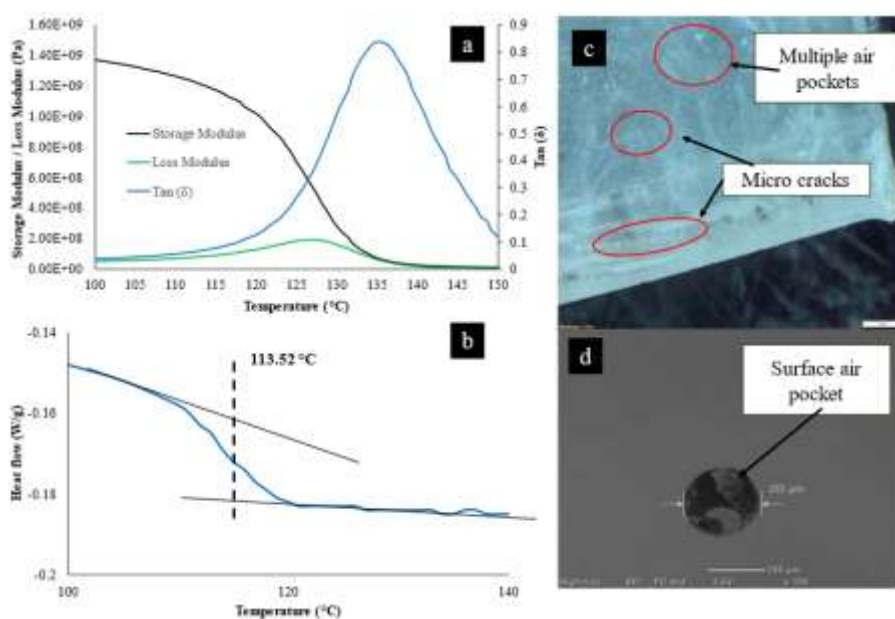
Fig. 2. Glass transition temperature evaluation using (a) DMA graph of the SMP and (b) DSC graph of the SMP. (c) Air pockets and micro-cracks in the SMP from the stereo microscope and (d) Scanning Electron Microscope (SEM).

A stereo microscopy and SEM were used to closely observe the surface structure of the SMP. It was observed that air pockets (~255 μm wide) and micro-scale cracks in the specimen, as shown in Fig. 2(c)**Error! Reference source not found.**. This can lead to poor shape memory behaviour and failure of the SMP finger during the programming stage. However, extending the vacuum degassing time can be used to avoid such morphological defects.

3.2 Performances of SMP Finger

The movement of the SMP fingers upon heating was observed, as shown in Fig. 3(a). After shape recovery, the Recovery factor (Rf) was calculated by using the percentage value of the recovery angle divided by the deformed angle. As shown in Fig. 3(b), the SMP finger took 362 s to recover its original shape (from 146° to 137°) with a Rf of 98.08%. It was observed that specimens with higher air pockets show a weak shape recovery process. The force generated on the plastic ball during the shape recovery process was recorded from the FSRs. And the data was collected to compare with future experiments. The purpose of measuring force was to control the pressure generated by the gripper on handling fragile objects. Force was measured in three different time intervals: 89 s, 142 s and 362 s. According to the force measurement from FSR1 on the SMP finger, the final stage of the recovery showed a maximum force of 5 N.
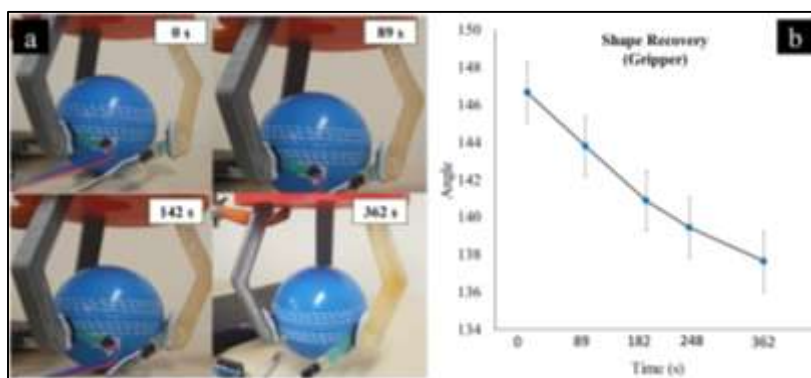
Fig. 3. (a) SMP finger recovery process in the gripper assemblies and (b) shape recovery of the SMP finger within 362 s

4. CONCLUSIONS

As the primary objective, designing, fabricating and operating the SMP actuator for the soft robotic gripper was accomplished. Heat simulation of the fabricated finger (actuator) was effective and has shown the potential for real-world applications. The force generated (5 N) on the objects by the finger is acceptable, and further studies are warranted to develop a force-controllable gripper. Air pockets caused microcavities and cracks in the SMP finger during the curing process. These air pockets can cause weak SMP shape memory and mechanical properties. Therefore, it is essential to minimize the air in the SMP uncured mixture by increasing vacuum degassing time.

The information gathered on the SMP soft robotic gripper can be used for further development. SMPs with faster recovery and lower activation temperatures can be an initial optimisation for the assembly. Finally, an intensive research study is needed to develop reversible or bidirectional SMPs with fast actuation time to gain a competitive advantage over electromechanical robotic grippers.

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A COMPARISON OF FOUR GROUND ELECTRICAL RESISTIVITY SURVEY (GERS) ARRAY METHODS USED IN INVESTIGATING INJECTED GROUTING: A CASE STUDY OF THISSA DAM IN SRILANKA

M. D. J. P. Wickramasooriya*
Irrigation Department, Sri Lanka
janakapriyantha1986@gmail.com*

ABSTRACT: The Thissa reservoir with a capacity of 4.32 million cubic meters is situated in Thissamaharama in Hambanthota district about 250km South from Colombo, Sri Lanka. Geologically, it lies within the litho-techtonic unit of the Vijayan Complex in Sri Lanka. For several years, the Thissa reservoir has experienced seepage issues, posing potential risk to the earthen dam. To address these problems, a rehabilitation study using the two-dimensional Ground Electrical Resistivity Survey (2D-GERS) method and the clay-cement grouting method was conducted. The 2D-GERS method, a geophysical method for detecting subsurface or rock anomalies, was used to compare four electrode array configurations: Dipole-Dipole, Gradient-XL, Schlumberger and Wenner. These arrays helped identify injected grout and seepage zones beneath the Thissa *wewa* earthen dam. The objective of this study was to compare the performance of four arrays, assessing seepage after the clay-cement grouting treatment. The analysis of the 2D-GERS profiles at seepage locations along with the grouting results shows that the 2D-GERS method can serve as a cost-effective investigation method for assessing the seepage locations through earthen dams. The areas of heavy cement-clay grouting are clearly delineated by the 2D-GERS profiles from the different array methods. The Dipole-Dipole array recorded the largest dataset (1149 points) and reached greater depths and was faster compared to the others. In contrast, the Wenner array had the smallest dataset (345 points) and captured shallower depths. The Wenner, Gradient-XL (1030 points) and Schlumberger (748 points) arrays produced relatively similar profiles. However, it was noticed that the Dipole-Dipole array was less sensitive compared to the other three arrays. Overall, the Gradient-XL and Schlumberger arrays captured the grout intake at an acceptable level.

Keywords: dipole-dipole, gradient-XL, schlumberger, wenner

1. INTRODUCTION

Most of the dams in Sri Lanka, built across rivers, are earthen dams, and excessive seepage through these structures has become a recurring issue. The main purpose of most dams is to store water for use in dry periods. Therefore, it is crucial to minimize seepage to ensure both the stability of the dam and the maintenance of secure water storage in the reservoir. The Irrigation Department of Sri Lanka (IDSL) manages most of the country's large dams. Some of the earthen dams maintained by the IDSL were constructed during the reigns of the kings. Recently, seepage has become visible through some of these historic dams including the Thissa reservoir. Geologically, the Thissa reservoir is located within the Vijayan Complex litho-tectonic unit (Fig. 1). Excessive seepage in the dam was investigated using cost-effective geophysical methods. The Ground Electrical Resistivity Survey (GERS) was used to investigate the seepage locations by identifying anomalies in the earthen dam before and after treatments. Based on the recommendations of the Engineering Geology Division (EGD) of the IDSL, clay-cement grouting treatments were implemented to address the seepage issue.

Fig. 1. Location of Thissa dam

The main purpose of grouting is to densify the soil and minimize the voids in soil and gaps in fractures or fissures in rock. Clay-cement grouting involves injecting a slurry mixture of clay, cement, water, and other additives into the voids, cracks, or porous zones within the dam structure or foundation. The process aims to fill these gaps, reducing permeability and enhancing the structural cohesion of the dam. The mixture is injected under pressure through strategically placed boreholes, allowing it to penetrate and fill the targeted areas. Once the grout sets and hardens, it forms a dense, impermeable barrier that strengthens the dam and prevents water seepage. In the grouting industry, various materials can be found which have been used to increase

the density and seal the voids in soil. Chun et al (2006) have successfully controlled leakage in an earth- fill dam in Korea through application of permeation grouting.

The GERS is a geophysical method used to investigate subsurface properties by measuring the ground electrical resistance. Several array methods are available, each suited to different types of investigations, including Wenner, Schlumberger, Dipole-Dipole and Gradient-XL arrays. Each method offers distinct advantages and limitations, with the choice depending on the survey's specific objectives and conditions. Wickramasooriya et al (2023) carried out a GERS in Uyanwewa Dam in Sri Lanka and successfully investigated seepage locations during clay-cement grouting. Even though Wickramasooriya et al (2024) assessed the applicability of GERS for identification of seepage in an earthen dam, a comparison of the array methods has not been performed yet for the Thissa Dam. Furthermore, Wickramasooriya (2024) concluded that the Schlumberger method is well accepted for delineating the subsurface materials in the Ellewewa Reservoir Project in Sri Lanka and has identified GERS as a more economical method for investigating subsurface materials, compared to traditional borehole drilling. In contrast, the Wenner array was identified as superior over the Dipole-Dipole array by Neyamadpour et al. (2010) during a three-dimensional electrical resistivity imaging study aimed at determining an underground cavity in Malaysia. Moreover, three array methods were compared by Al-Saady et al. (2022) in a 2D resistivity survey in Iraq to determine subsurface weak zones and concluded that the Dipole-Dipole array is the optimum method for mapping subsurface weak zones. Himi et al. (2018) successfully detected seepage and injected mortar zones by geophysical methods. However, it appears that a comprehensive study of all four methods in GERS along with an assessment of their applicability has not been sufficiently carried out in the Sri Lankan context.

2. METHODOLOGY

A few years after leakages were observed along the downstream (DS) face of the Thissa dam, as a quick and economical investigation method in geophysics, the GERS along the bund top was used here to identify leakage paths. These investigations identified three locations (Fig. 2) with significant seepage issues.

The EGD of IDSL recommended grouting the identified bund sections (Sections A, B and C) up to a maximum depth of 12 m in overburden with proper ratios of clay and cement, and in rock up to 24 m with cement grout to arrest water leakages as necessary. Two rows of grout holes were planned in a zigzag pattern with 3 m spacing between two holes within a row and 1.5 m spacing between the rows. The shortest distance between nearest holes was 2.12 m. After grouting, only section C was investigated using the four different GERS methods of fixing electrodes as in Fig. 3. ABEM Terrameter LS2 instrument and RES2D software were used for the GERS analysis. All four GERS profiles were compared to the actual amounts of grout and assessed, each with different levels of acceptance.

Fig. 2. Seepage locations

Fig. 3. Ground Electrical Resistivity Survey (GERS) at Thissa dam

3. RESULTS AND DISCUSSION

The locations where the dam received peak grout values were marked and compared with the GERS profiles. A total of ten peak points were identified and they were categorized based on how accurately each method captured grout injection into the dam as shown in Table 1. It was assumed that the clay grout had a resistivity value ranging from 0 to 30 Ωm.

Table 1. Capturing of Grouting by Each Method of Arrays

Peak point	Dipole-Dipole	Gradient-XL	Schlumberger	Wenner
A	NC	NC	NC	NC
B	NC	MC	NC	NC
C	MC	NC	MC	MC
D	MC	WC	WC	WC
E	WC	WC	WC	MC
F	WC	WC	WC	WC
G	WC	WC	WC	WC
H	WC	WC	WC	WC
I	MC	WC	WC	WC
J	MC	MC	MC	MC

Note: WC = Well Captured, MC = Moderately Captured, NC = Not Captured
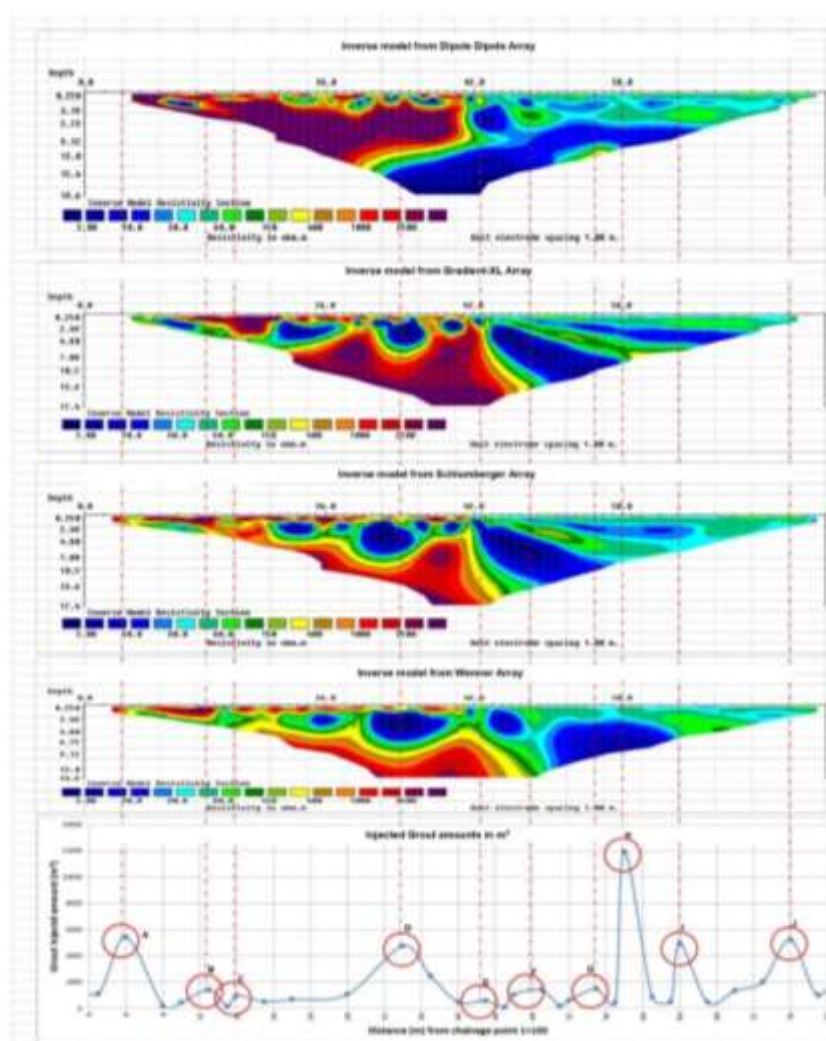
Fig. 4. Comparison of GERS performance with the injected grout amount

It was observed (Fig. 4) that none of the four array methods was able to detect the peak grout intake at the starting edge of the profile. As noted by Wickramasooriya (2024) the GERS method is less suitable to get subsurface materials in the edges of the profiles. The Dipole-Dipole array method captured well only the middle area of the profile while the other array methods captured a comparatively wide range of areas effectively. However, the Dipole-Dipole array method reached the greatest depth recording 19.6 m depth, which is the maximum among the methods. It was noticed that non-grouted areas between 24 m to 28 m were incorrectly shown in Gradient XL, Schlumberger and Wenner arrays as low resistivity areas. This is due to the existing high moisture content of the soil due to the availability of trees on the dam.

Table 02 tabulates the WC, MC and NC values as per their identification of the injected grout zones. As tabulated in Table 02, the dipole-dipole array method was identified as less sensitive than the other three arrays, because it has a smaller number of Well Captured (WC) zones. The WC zones are higher (Table 02) in the Gradient XL and Schlumberger method arrays for identifying the injected mortar.

Table 2. Capturing Performance of Each Array Method

	Dipole-Dipole	Gradient-XL	Schlumberger	Wenner
WC	4	6	6	5
MC	4	2	2	3
NC	2	2	2	2

The GERS method was very cost-effective; one GERS profile would cost around 0.1 Mn (LKR) approximately (without the instrument cost) while traditional borehole drilling costs about 1 Mn (LKR) approximately for one bore hole. Furthermore, GERS provides comparatively broad, continuous coverage over a large area and traditional bore hole drilling provides point-specific data with high accuracy at each point.

4. CONCLUSION

The areas where cement-clay grouting was heavily applied were clearly identified using 2D-GERS profiles from various array methods. The Gradient-XL and Schlumberger methods proved to be superior compared to the others. The dipole-dipole array captured comparatively greater depths and was quicker than others but less sensitive, while the Schlumberger array took a longer time compared to other methods.

In conclusion, GERS can be identified as a more economical method of investigation compared to traditional borehole drilling. However, there are limitations in the level of acceptance in each array type. Further studies could compare the grout injection variation with depth to enhance precision. Furthermore, GERS can play a critical role in the planning, design, construction, operation, decommissioning, and closure of water resources or tailings dams.

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INTEGRATION OF DIGITAL TWIN TECHNOLOGY FOR ENHANCING SUSTAINABILITY IN BUILDING LIFECYCLE: A SYSTEMATIC REVIEW

H. A. D. G. S. Jayathilaka[1*] and T. M. P. Malshan[2]

[1, 2]Institute of Technology University of Moratuwa, Sri Lanka

gaindus@itum.mrt.ac.lk[1*], malshanp@itum.mrt.ac.lk[2]

ABSTRACT: A Digital Twin (DT) can be defined as a virtual replica of a physical entity that imitates the state of its physical counterpart in real-time. It consumes real-time data from a physical entity, such as performance metrics, and links the two entities for synchronization and feedback between the digital and physical worlds, which adapt throughout the physical entity's lifecycle. DT can be used for various applications, including real-time monitoring, predictive maintenance, and optimization of processes in various areas. Sustainable construction is a prominent area that has recently drawn a significant research interest in DT. Since there is a lack of systematic reviews on this consideration, the present study aims to explore the recent efforts to utilize the DT concept in sustainable construction. Within the broad area of the construction industry, this study primarily focuses on each phase of the building lifecycle where DT can be adopted to enhance sustainable performances. A systematic literature review was conducted to identify the latest scholarly publications on the Digital Twin concept and its potential applications across each phase of the building lifecycle to improve sustainability. The findings of the study mainly reveal that the DT technology is emerging as a powerful tool to improve sustainability performances throughout a building's lifecycle. However, a limitation was identified in research literature and case studies related to integrating DT technology to improve sustainability in the demolition phase. One of the main contributions of DT to sustainable construction is enabling real-time monitoring and analysis at each phase of the building lifecycle. This allows for optimizing energy and resource consumption, which leads to reducing carbon emissions in each phase. Predictive maintenance, enhanced collaboration among stakeholders, efficient management of manpower, machinery and equipment are the other key areas where DT has contributed to sustainability throughout a building's lifecycle.

Keywords: building lifecycle, construction industry, digital twin, sustainability, sustainable construction

1. INTRODUCTION

With the emergence of in Industry 4.0, Digital Twin (DT) has become a crucial technology, offering numerous advantages throughout the product's lifecycle (Sun et al., 2024). Moreover, DT plays a pivotal role in shaping the industry 5.0 by supporting its three main pillars identified as human-centric, sustainable, and resilient industry transformation (Barata & Kayser, 2024). Due to the rapid development of the construction industry and the drastic increase in the need for the digitalization, is a considerable potential to integrate DT into the industry (Jiang et al., 2021). DT technology consists of three components: a physical entity, a digital replica of that physical entity and the connections of data and information between that physical entity and the digital model (Jones et al., 2020). With these three components, DT allows real-time surveillance, mapping and data evaluation, followed by the decision making, in the construction industry (Kamari & Ham, 2022).

Sustainable practices ensure a viable future for the construction industry by balancing the environmental, social and economic considerations. There is a high capacity to enhance sustainability in the construction industry by adapting DT into sustainable construction practices (Zhang et al., 2024). A study by Kaewunruen et al. (2020) revealed that by adopting DT, stakeholders can identify issues and execute strategies to improve sustainable performances throughout a project's lifecycle in the construction industry. A comprehensive review of the applications of DT technology across the different phases of a project's lifecycle to enhance sustainable performances is lacking in the construction industry. Therefore, this study aims to address this gap by developing a systematic review on integrating DT technology to improve sustainability throughout the building lifecycle.

2. METHODOLOGY

A systematic literature review was employed to address the research question: What are the applications of Digital Twin (DT) technology in addressing sustainability challenges across various

stages of the building lifecycle?" This research question was framed within the scope considered for the present study. With the aim of enhancing the sustainability of the construction industry, the above research question was developed to include basic concepts, theories, recent developments, and trends in DT technology integration in the building construction industry. A combination of key terms, Digital Twin, Building Construction Industry, Sustainable Construction, Building Lifecycle and Sustainability, was used to develop a search query to obtain the relevant research articles related to the above research question. A detailed representation of the methodology followed for the systematic literature review is shown in Fig. 1.
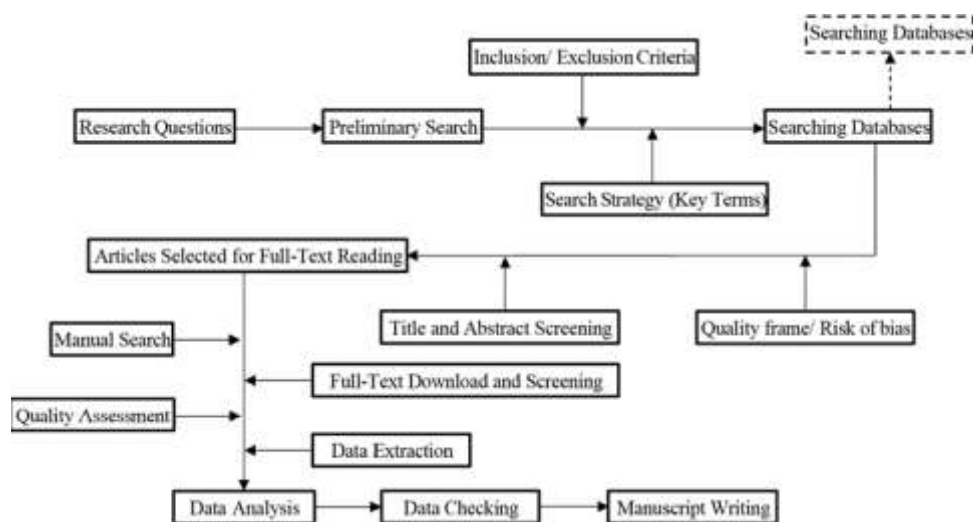
Fig. 1. Steps Followed for the Systematic Literature Review

Research articles published in journals, conferences, and book chapters on DT technology and its application in the sustainable construction industry were considered as inclusion criteria. Additionally, only articles published within the last five years and available in Science Direct, Scopus and Web of Science were included. A total of 55 research articles were ultimately analysed for this systematic literature review. There, various criteria were utilized to select the appropriate articles under the "Title and Abstract Screening" and "Full Text Download and Screening" steps.

3. RESULTS AND DISCUSSION

This section presents the main findings of the systematic literature review. The key applications of DT technology across the four main phases of the building lifecycle, aimed at enhancing sustainability performances are presented in the following four sub sections.

3.1 Planning and Design

Analysing and forecasting energy consumption to optimize it is one of the key methods by which DT can be utilized during the planning and design stage to improve sustainability (Bocullo et al., 2023). For instances, a DT model can be developed to demonstrate the solar chimneys integration and predict the impact of double layer façade systems on energy storage (Tariq et al., 2022). Both examples highlight the considerable operational cost reductions compared to repetitive physical models. By integrating DT, rework costs can be reduced, allowing designers to use acquired data for future endeavours (Singh et al., 2022). Furthermore, the DT technology has been adapted to optimize material utilization by developing and analysing a model in a virtual space (Su et al., 2023). Moreover, DT can be incorporated into sustainable assessment in this phase by evaluating user centered sustainability criteria and executing analyzing (Tagliabue et al., 2021).

3.2 Construction Phase

Integrating DT during the construction phase is crucial due to high resource and energy consumption. DT enables virtual mapping and real-time monitoring of construction sites, supporting detailed analysis to optimize the energy and resources consumption (Su et al., 2023). By collaborating with Light Detection and Ranging technology DT technology has been adopted to minimize material wastage (Mêda et al., 2023). Moreover, the DT technology can be used to enhance the sustainability of the material production by reducing carbon emissions (Metallidou et al., 2022). Additionally, other advanced technologies like 3D printing can be incorporated with the DT technology to enhance material performance and overall construction sustainability (Wang et al., 2023).

3.3 Operation and Maintenance Phase

DT technology has been predominantly integrated into this phase through real-time management systems for electrical equipment, enhancing sustainability by optimizing energy consumption and minimizing the carbon emissions (Mohseni et al., 2023). Artificial intelligence combined with DT predicts the energy demand and enhances the efficiency of the systems like HVAC by addressing individual thermal preferences of occupants (Clausen et al., 2021). With the integration of Building Information Modelling (BIM) technology, DT can be utilized to enhance the energy efficiency of indoor lighting (Tan et al., 2022). Smart maintenance and automated inspection mechanisms such as detecting structural cracks have been adopted with DT technology, enabling autonomous maintenance mechanism that reduce energy and resource consumption while mitigating unnecessary maintenance costs (Loverdos & Sarhosis, 2023).

3.4 Demolition and Recovery Phase

While studies on DT technology in the demolition phase are limited, DT can be utilized to develop a real-time model to track the location and working condition of staff vehicles, machinery, and equipment, minimizing resource and energy consumption (Omrany et al., 2023). Circular Economy can be incorporated with DT technology in the construction industry to overcome challenges in demolition phases such as optimize waste generation and disposal (Meng et al., 2023). The Monte Carlo simulation was utilized by (Züst et al., 2021) with DT technology to highlight an effective method of managing the demolition material. Additionally, (Zheng et al., 2022) has used DT technology to investigate a method to avoid accidents during the demolition phase, thereby reducing the casualties and improving the social comfortability during this phase.

4. CONCLUSION

The present systematic review underscores the significance of DT in enhancing the sustainability of the throughout the building lifecycle. The DT concept has been utilized in various ways throughout each phase of building lifecycle, often in combination with the latest technologies such as IoT, Artificial Intelligence and Machine Learning. Optimizing energy consumption is the prominent sustainability factor that DT successfully integrates into each phase. Additionally, DT technology has been adopted to achieve efficient material and resource consumption and reduce carbon emissions in planning and design, construction, operational and maintenance phases. However, limited research and case-studies were found related to DT application for sustainable practices in the demolition, despite the potential benefits for material recovery and risk mitigation. Therefore, as a future recommendation, it would be beneficial to focus on applying DT in demolition phases as it plays a crucial role in maintaining sustainability. Further empirical studies and quantitative data are needed to validate the findings of the present review and fully explore DT's potential to enhance sustainability throughout the building lifecycle.

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DETERMINING THE OPTIMUM FOCAL HEIGHT OF A PARABOLIC TROUGH CONCENTRATOR USING AN OPTICAL METHOD

M. P. S. Viraj[1], P. D. C. Kumara[2*], and H. H. E. Jayaweera[3]

[2] Institute of Technology University of Moratuwa, Sri Lanka

[1,2,3] Centre for Instrument Development, Department of Physics, University of Colombo, Sri Lanka

[1] Department of Physics, University of Bologna, Italy

sameera.malwaththa@studio.unibo.it[1], ckumara@itum.mrt.ac.lk[2*], hiran@phys.cmb.ac.lk[3]

ABSTRACT: This study investigates the optimal focal height of a Parabolic Trough Concentrator (PTC) solar thermal plant, a key parameter affecting its overall performance. The dimensions of the PTC module are $4.5 \text{ m} \times 4.8 \text{ m}$ with an aperture area of 20.3 m^2. Unlike diffuse solar systems, the effectiveness of a concentrated solar thermal plant is highly dependent on factors such as the parabola's concentration ratio and geometrical parameters. This paper presents an optical/photographic approach to determine the optimum focal height of the PTC while harnessing solar thermal energy. The findings highlight the importance of maintaining accurate geometric parameters over time due to structural deformations, environmental conditions, and aging effects. The theoretical focal height of the PTC module was calculated as 1700 mm at the design stage. A laser scanning mechanism revealed that the actual focal height of the PTC module was 1830 mm after manufacturing, when the parabolic reflective mirror was rotated to point towards the ground, and the laser pointers were fired vertically upwards to ensure they were perpendicular to the focal plane. A digital single-lens reflex (DSLR) camera was used to capture the focused solar concentrated beam on the target board. The findings verified that the optimum focal height of the PTC module is 1675 mm while harnessing solar thermal energy.

Keywords: optical methods, optimum focal height, parabolic trough concentrator, solar thermal energy, thermal distribution measurement

1. INTRODUCTION

The Parabolic Trough Concentrator (PTC) plant at the University of Colombo premises measures $4.5 \text{ m} \times 4.8 \text{ m} \times 3.0 \text{ m}$, and the weight is calculated as 2.5 Tons (See Fig. 1). The effective aperture area of the PTC is designed to be 20.3 m^2. The thermal energy harnessing capacity of PTC was calculated as 18.2 kW by considering the solar irradiance as 900 kW/m^2. The main objective of this research study is to experimentally determine optimum focal height of the PTC module and investigate the variation of focal height due to structural deformations, environmental conditions, and aging effects.

Fig. 1. PTC plant at the faculty of Science, University of Colombo

The precise optical geometry of the PTC systems will be maximizing its energy harnessing efficiency. Factors like aperture size, rim angle, focal height, and mirror surface quality significantly impact their performance (Meiser *et al*., 2017). Even minor deviations in these parameters can lead to substantial losses in the optical efficiency of the PTC system (Arun *et al*., 2024). This paper

discusses an optical method using photographic analysis to determine the optimal focal height for a PTC plant.

2. METHODOLOGY

This PTC module was designed to maintain the theoretical focal height of 1700 mm when the rim angle was 80^0 according to the scale of the PTC module (Brooks and Harms, 2014; Mwesigye, Bello-Ochende and Meyer, 2014; Good *et al*., 2016; Murtuza *et al*., 2017) and mirrors were constructed by using 3M reflective mirror films with more than 93% reflectance over 14 years (3M, 2017). A railing platform was fabricated to investigate focusing performance of the parabolic shape reflectors and get the actual focal height of the PTC module. A laboratory optical bench was modified with four numbers of nylon wheels to facilitate moving on the railing. A mild steel box iron of 2 inch $\times$ 2 inch and 8 feet of length was placed on the optical bench with the mountings, and 8 number of red (680 nm) diode laser pointers were mounted to the box iron with three degree-of-freedom mounting with the linear moving facilities to maintain the high accuracy of evaluation of parabolic shape and the measurement of actual focal height (Fig. 2A). The parabolic reflective mirror was rotated to point towards, the ground, and the laser pointers were fired vertically upwards to ensure they are perpendicular to the focal plane. This allows us to assume that the laser beams mimic the solar beam when the mirror points toward the sun. A target board was placed on the focal line parallel to the focal plane. The ideal focus (zero deviation) line was at the middle and edges of the Ø 70 mm receiver tube was in both sides of the ideal line (Fig. 2B). The scanning was done along the centre axel for both sides of the parabola while varying the focal height. This method was used to measure the actual focal height of the PTC module.
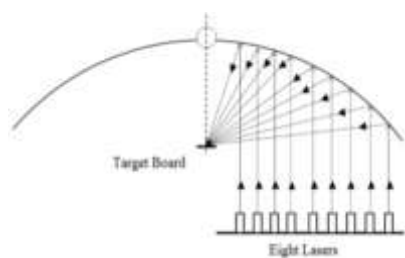
Fig. 2A. Laser scanning along the axial direction of the PTC
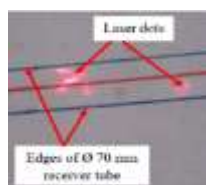
Fig. 2B. Reflected laser beams on target board

Fig. 2C. Photograph of laser scanning mechanism developed to measure the actual focal height of the PTC module

Even though the PTC module was evaluated with the above mechanism in theoretical condition, the practical values of the focal height and the rim angle can be differed while harnessing solar energy, due to the weight of the mirror corners, wind load, and loss of the strength of the structure. Therefore, measuring the deviation and making the necessary corrections to keep the PTC in optimum focus is crucial. The following optical method was developed to measure the optimum focal height at the running condition.

An optical technique was introduced with the use of a Digital Single Lens Reflex (DSLR) camera (Canon EOS REBEL T6i) with an EF-S 18-55 mm lens. The camera was used to take photographs of the focused solar beam falling on the target plane. A white colour-washed asbestos sheet served as the target board with black reference markings to assist in analysing the intensity distribution of the concentrated beam (Fig. 3). Photographs were taken at the six different heights used in the thermal distribution experiment, with the following camera settings: aperture - f/22, shutter speed - 1/3200, ISO - 100. The captured images are then processed to get the intensity distribution across the focused beam to identify the best focal line.

Fig. 3. Prepared target board with white and black references

3. RESULTS AND DISCUSSION

The PTC module's primary function is to focus direct solar radiation onto the receiver tube. Therefore, it is essential to position the receiver tube on a precisely focused plane. For this, the right focal height of the parabola must be determined. According to the system's design specifications, the theoretical focal height of the parabola was predicted to be 1700 mm. Through the laser scanning mechanism revealed that actual focal height of the PTC module as 1830 mm after manufactured. This difference might be caused due to the deformations of the structure and tolerances in the manufacturing processes. However, the PTC module's primary function (module efficiency) is mainly dependent on the optimum focal height while harnessing solar thermal energy. As a solution for this, experimental setup was devised to determine the optimum focal height by analysing the intensified distribution of the images taken at different heights when the system is harnessing the solar thermal energy.

The experiment was conducted to find the ideal focal height by evaluating photographs of the focused beam at each test height. Fig. 4A depicts photographs of the concentrated beam at six distinct test heights, whereas Fig. 4B illustrates the intensity distribution across the concentrated beam for each set of images. The identical camera settings and equipment as mentioned in methodology were used for all photos, and perception error correction and scaling were performed prior to analysis.

Although the photos provide a clear visual representation of the focal height of the PTC, the full width at half maximum of the Gauss curves fitted to the intensity data was calculated to scientifically prove it. The graph below depicts the behaviour of those determined FWHM values of fitted Gaussians. According to those FWHM values (Fig. 5), the narrowest intensity distribution was obtained at 1675 mm height, which confirmed the results of the previous experiment as well.

| 1625 mm | 1650 mm | 1675 mm | 1700 mm | 1725 mm | 1750 mm |
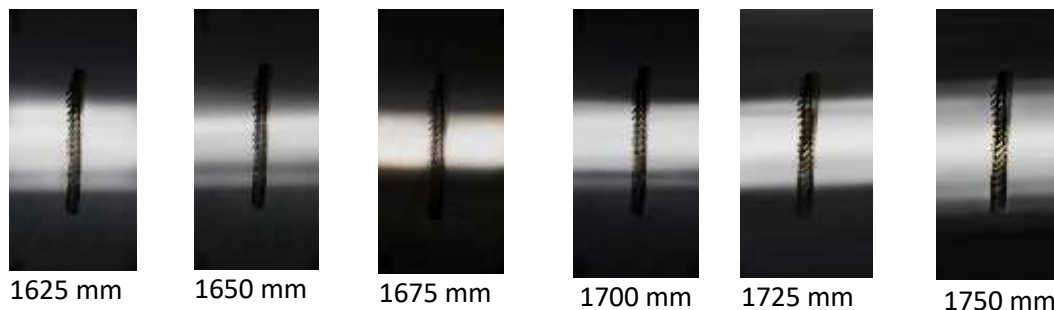
Fig. 4A. Photographs of the concentrated beam at six test heights. Please note that the perception error correction and scaling were done before analyzing the images
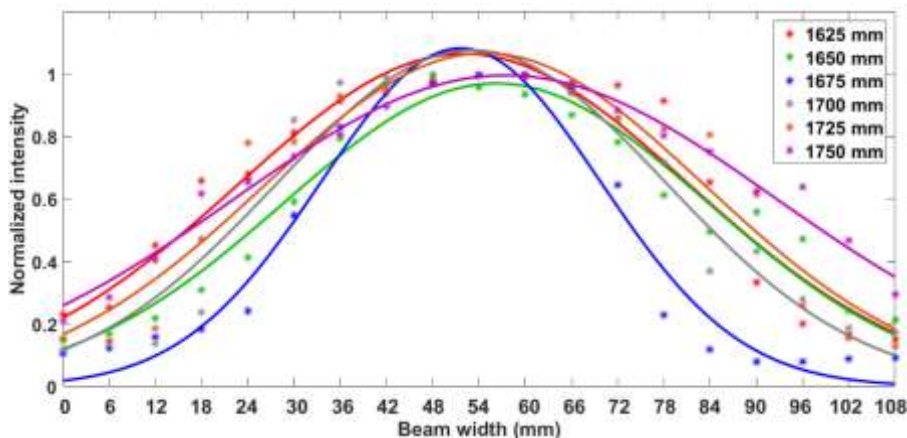
Fig. 4B. Intensity distributions of analyzed images of focused line
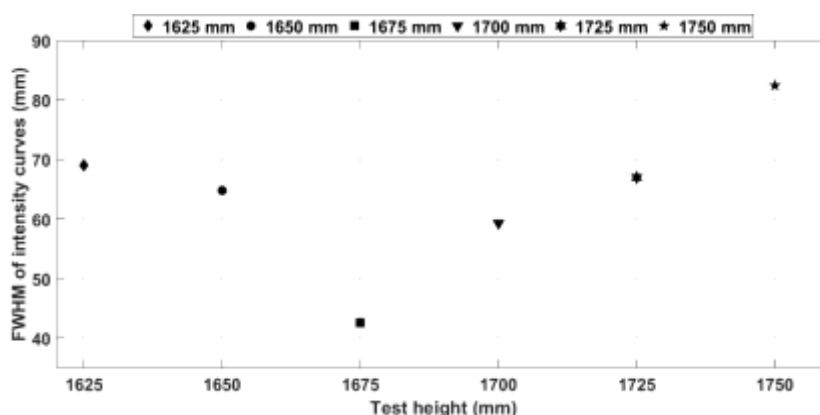
Fig. 5. Full width at half maximum values of intensity distribution curves of each test height

4. CONCLUSION

The optimal focal height of the PTC was obtained by analysing images of the concentrated beam. So, the optimum focal height for the PTC was found to be 1675 mm while harnessing the solar thermal energy. At this height, the system also reached its highest temperature. The PTC consists of two reflector mirrors, and it was also found that there is no difference in the focal height of each segment. Moreover, this investigation also discovered that the maximum beam width with more than 50% intensity at the focal height is 50 mm.

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DEVELOPMENT & EVALUATION OF JACK OPERATED HERBAL JUICE/OIL EXTRACTOR FOR AYURVEDIC MEDICINE PREPARATION

KYHD Shantha[1*], PMYS Pathiraja[2], YMMK Ranatunga[3], and KMW Rajawatta[4]

[1,2,3,4] Department of Agricultural Engineering & Post Harvest Technology,
National Engineering Research & Development Centre of Sri Lanka
[4]Department of Biosystems Technology, Faculty of Technology, University of Ruhuna, Sri Lanka

harsha@nerdc.lk[1*], ypathiraja@gmail.com[2], maliniranatunge@gmail.com[3] wathsala@btech.ruh.ac.lk[4]

ABSTRACT: Sri Lanka has a rich indigenous system of traditional medicine known as Ayurveda, which combines Sinhala traditional medicine, Indian Ayurveda and Siddha systems, Greek Unani medicine through Arab influence, and the unique Desheeya Chikitsa. The objectives of this research were to identify the essential practices for equipment development in the Ayurvedic sector, to examine the scientific principles underlying traditional practices, and to design Ayurvedic machinery. To achieve these goals, a needs identification survey was conducted involving over 10 institutes in Sri Lanka and more than 300 indigenous doctors across the country. Data were collected from 120 of these doctors to ascertain the specific requirements of the sector. In Ayurvedic preparations, herbal juice extraction is done manually, and 'Pehe' is used to extract oil from hard materials like "mee" and to extract the remaining oil from Kalka, making the process time-consuming and labour-intensive. To address this challenge, a hydraulically operated juice/oil extractor was designed to fulfil one of their requirements. This machine operates at low temperatures, which helps to preserve the nutrients and flavour of the juice/oil. It is operated using 4-ton hydraulic jack. Extracted juice percentages (wet basis) were 65% and 60% for Gotukola and Neeramulliya leaves respectively. Extracted oil/juice % (wet basis) were 36%, 48.89%, 19.8%, 20.4%, 68.52% and 52% for Mee (without steaming), Mee (steamed), Sesame (black), Sesame (normal), Nelli (without seeds) and Nelli (with seeds) respectively. Results revealed that using this method juice/oil can be extracted efficiently using this extractor than traditional methods. An extractor is a portable device which can be operated by a single person. Since the raw material contaminating machine components of the extractor are made of food-grade stainless steel, the hygienic extraction process is secured. The extractor has a capacity of approximately 3 kg of crushed leaves or 1 kg of crushed seeds per batch. Over 100 machines have been distributed to small and medium-scale Ayurvedic practitioners involved in medicine preparation.

Keywords: Gotukola, hydraulic jack operated, juice/oil extractor, Mee, traditional medicine

1. INTRODUCTION

The history of indigenous medicine in Sri Lanka is deeply intertwined with the origins of the Sinhalese nation. This medical practice, rooted in traditional knowledge, has been influenced by Ayurveda from Northern India, Siddha from Southern India, and Unani from the Arabic region (Weragoda, 1980; Perera PK, 2012). During the Colonial era, indigenous medical practices faced significant suppression, while Western medicine gained prominence as the dominant national health system throughout the island (Perera PK, 2012).

Currently, over twenty thousand traditional Ayurvedic doctors are practicing in Sri Lanka. These practitioners face numerous challenges in preparing specialized Ayurvedic medicines, primarily due to a lack of suitable small-scale equipment (Perera PK, 2012). Consequently, the development of appropriate equipment and processes is crucial for efficiently producing medicines needed by both Ayurveda and traditional Ayurvedic practitioners (Hapugahakotuwa, 2024).

To address this issue, a needs identification survey was conducted to ascertain the specific requirements of the Ayurvedic sector. Various methods were employed to gather information from different stakeholders.

2. METHODOLOGY

For the needs analysis, we visited several key institutes, including the Ayurveda Research Institute in Navinna, Ayurveda Hospital in Borella, Sri Lanka Ayurvedic Drug Corporation, Gampaha Wickramarachchi Institute, Gampaha Wickramarachchi Ayurveda Hospital, and the Department of Indigenous Medicine at Colombo Municipal Council (Dematagoda). Further, we collected

information from participants at two workshops organized by the Ministry of Indigenous Medicine and the NERD Centre. Based on the preferences of participants and other relevant stakeholders, the following requirements were identified:

1. Development of machinery for the Ayurvedic sector, including small-scale machinery for the preparation of 'Guli'; Equipment for producing uniform fine powder; Methods for minimizing powder wastage during preparation; A cutter for processing hard medicinal woods; An oil expeller for extracting juice/oil from leaves and seeds.
2. Investigation of the temperature profile of traditional Puta furnaces used in the preparation of Ayurvedic metallic ash (Bhasma).

Among these, we selected the development of a juice/oil extractor, which was named the Jack Operated Juice/Oil Extractor. Initially, we explored indigenous methods, including the scientific principles behind the 'Pehe' and 'Sekkuwa' techniques. Based on these principles, the design and fabrication processes were initiated. In addition, the need of a crusher machine for crushing hard seeds and dried herbs into powder and fresh herbs into smaller size prior to extracting squeezing process of juice/oil.

Having understood the significance of these two major requirements, two essential machines were successfully designed and developed: a crusher for seeds, dried herbs, and fresh herbal leaves, along with a hydraulic jack-operated herbal juice/oil extractor for simultaneous juice and oil extraction. These two machines were designed as simple devices with reliable and durable machine elements considering the operational feasibility in the aspect of ergonomics.

At first, herbal leaves were crushed into smaller size using the crusher before feeding into the hydraulic jack operated juice/oil extractor for extracting juice. Likewise, the seeds to be tested are also got crushed using the same crusher before feeding into the same juice/oil extractor for extracting oil for verity of seeds. Results of juice and oil extraction processes carried out for two verities of herbal leaves and four verities of seeds at different test conditions are listed in the Table 1 and Table 2.

3. RESULTS AND DISCUSSION

Fig. 1 and Fig. 2 illustrate the main components of the two fabricated machines, while Table 1 and Table 2 present the results of the field trials. During the trials, wastage was minimised (5g<) and considered negligible. All trials were conducted in collaboration with respective Ayurvedic doctors. This method is simple and requires less human effort compared to traditional methods, making it easy and efficient for a single operator to manage.

Specifications of the Crusher Used for Herbal Leaves & Seeds

Power Requirement - 1.5 hp, Single Phase

Capacity   - 15-20 kg of leaves/hr (approximately) or 35-40kg of seeds/hr (approximately)

Dimensions   - 760x620x920mm (LxWxH)

Total weight   - 54 kg
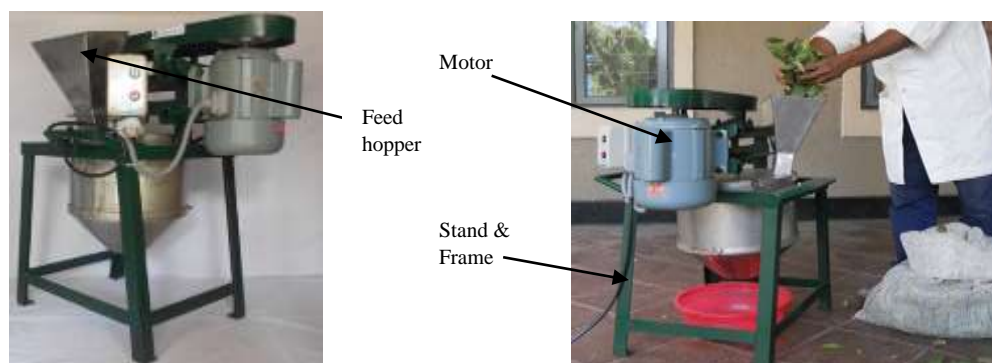
Fig. 1. Crusher for herbal leaves & seeds

Specifications of the Hydraulic Jack Operated Juice/Oil Extractor

Operated using 4-ton hydraulic jack
Capacity   - approximately 3 kg of crushed leaves or 1 kg of crushed seed per batch
Dimensions   - 370x280x1360mm (LxWxH)
Total weight   - 52 kg
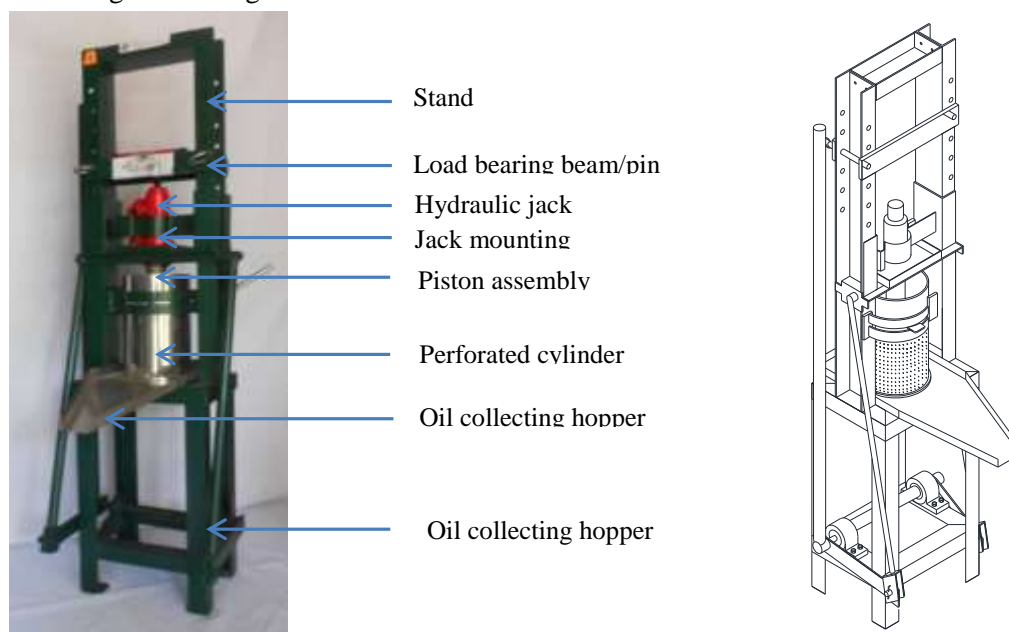
Fig. 2. Main components of the Hydraulic Jack Operated Juice/Oil Extractor

Table 1. Field trial results of crushed leaves

Material	Crushed leave quantity (kg)	Extracted juice quantity (kg)	Remaining pressed cake quantity (kg)	Extracted juice % (wet basis)	Average Extracted Juice % (wet basis)
Gotukola – Trial 1	9.00	5.80	3.20	64.44	
Gotukola – Trial 2	8.00	5.19	2.81	64.88	64.88
Gotukola – Trial 3	6.00	3.95	2.05	65.83	
Neeramulliya - Trial 1	13.00	7.60	5.40	58.46	
Neeramulliya - Trial 2	10.00	5.99	4.01	59.90	59.9
Neeramulliya - Trial 3	7.00	4.30	2.70	61.43	

Table 2. Field trial results of crushed seeds

Material	Crushed seed quantity (g)	Extracted oil/juice quantity (g)	Remaining pressed cake quantity (g)	Extracted oil/juice % (wet basis)
Mee (without steaming)	375	140	235	36.00
Mee (steamed)	450	220	230	48.89
Sesame (black)	1000	198	802	19.80
Sesame (normal)	1500	306	1194	20.40
Nelli (without seeds)	1620	1110	510	68.52
Nelli (with seeds)	3000	1560	1440	52.00

The trials revealed a significant increase in the yield of *Mee* oil when extracted from steamed *Mee* seeds compared to extraction without steaming. As per the views of the Ayurvedic doctors involved in the field trials, it was revealed that, there was a significant juice/oil increase, and a remarkable time decrease in using Hydraulic Jack Operated Herbal Juice/Oil Extractor for the extraction process compared to the traditional extraction method. With the success of the project, the Ministry of Indigenous Medicine requested the fabrication of more than 100 jack-operated juice/oil extractors (under project numbers A&PHT/COM/03/79/2014 and A&PHT/COM/03/141/2014) for distribution among Ayurvedic Sanrakshana Sabhas island-wide, as these machines are essential for improving the quality and efficiency of Ayurvedic drug preparation.

4. CONCLUSION

In response to the needs of the Ayurvedic sector, a jack-operated juice/oil extractor was developed. The extractor has a capacity of approximately 3 kg of crushed leaves per batch or 1 kg of crushed seeds per batch. These machines are primarily used by Ayurvedic doctors involved in small to medium-scale medicine preparation. The machine offers significant advantages in handling materials under hot conditions during the extraction process, designed to increase yield while eliminating practical challenges. Ultimately, over 100 jack-operated juice/oil extractors were fabricated and distributed island-wide. Feedback indicates that these machines are functioning well across all locations.

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UTILIZING SALVINIA MOLESTA FOR CELLULOSE PRODUCTION: AN ECO -FRIENDLY STRATEGY

A. R. Abeyweera[1*] and A. M. P. B. Samarasekara[2]

[1, 2] Department of Materials Science and Enginering, University of Moratuwa, Sri Lanka

abeyashani16@gmail.com[1*]; bandu@uom.lk[2]

ABSTRACT: *Salvinia molesta* is a very aggressive aquatic weed that poses a significant threat to water bodies worldwide. It invades quickly and disrupts ecosystems leading to serious environmental and economic problems. Traditional ways to control this invasive plant such as biological, physical or chemical methods have often proven ineffective. These methods can also be costly and labour-intensive. Recent research indicates that cellulose may offer viable alternatives. The research aimed at extracting high-purity cellulose from *Salvinia molesta* through a comprehensive pretreatment procedure. This procedure involves an initial Soxhlet extraction followed by an alkaline treatment and a bleaching process with the primary goal of isolating cellulose from the plant's biomass. The extracted cellulose was characterized using Fourier Transform Infrared Spectroscopy (FTIR) to confirm its chemical composition and Scanning Electron Microscopy (SEM) to assess its morphology. The FTIR analysis verified the successful isolation of cellulose while SEM imaging revealed well-preserved structural integrity, indicating high-quality cellulose extraction. These findings demonstrate that high-quality cellulose can be extracted from *Salvinia molesta*. This research presents an innovative and sustainable method for managing Salvinia *molesta* by converting it into cellulose, a biodegradable polymer widely used in the production of biodegradable composites suitable for diverse industrial applications such as packaging, bio-medical and textiles. This study significantly contributes to ecological restoration initiatives through the advancement of biodegradable materials, thereby fostering economic benefits.

Keywords: cellulose, FTIR, *Salvinia molesta*, SEM, sustainable material

1. INTRODUCTION

In recent decades, the environmental impacts of invasive plant species have received growing attention due to their harmful effects on biodiversity, water quality, and ecosystem stability. These impacts present both environmental challenges and potential opportunities. One particularly destructive aquatic invasive species is *Salvinia molesta*, which thrives in tropical and subtropical regions worldwide, which thrives in tropical and subtropical regions worldwide (Oliver, 1993).This fast-growing plant forms dense mats on water surfaces inhibiting light penetration, depleting oxygen levels and disrupting aquatic ecosystems. As a result, it reduces biodiversity, affects water quality and disrupts vital activities such as transportation, hydropower production, and fishing. Despite these environmental challenges, the plant also presents potential opportunities for resource utilization (Kariyawasam et al. 2021). Efforts to control *Salvinia molesta* through biological, chemical, and physical methods have proven costly and often ineffective, sometimes resulting in unintended side effects, such as nutrient leaching and greenhouse gas emissions from biomass disposal.

As a lignocellulosic fern, *Salvinia molesta* consists mainly of cellulose, hemicellulose, and lignin, along with essential nutrients like phosphorus, potassium, and calcium (Moozhiyil and Pallauf n.d.). Among these components, cellulose is one of the most abundant biopolymers; it is renewable, biodegradable, and integral to plant biomass. However, traditional cellulose sources, including wood, rice husk, bamboo, and cotton raise environmental concerns related to deforestation and high resource demands. Previous studies indicate that these sources were used to extract cellulose using methods such as chemical, enzymatic, ionic liquid and mechanical techniques (Giri and Adhikari 2013).Due to its high cellulose content and rapid growth rate, *Salvinia molesta* is a promising, sustainable lignocellulosic resource that does not compete with land use. Extracting cellulose from invasive plants like *Salvinia molesta* offers a dual benefit: it mitigates the ecological impact of invasive species while providing a sustainable alternative to traditional cellulose sources.

This study investigates an eco-friendly approach for extracting high-purity cellulose from *Salvinia molesta*, evaluating its potential as an alternative cellulose source. The complex structure of *Salvinia molesta* is effectively broken down through alkaline and delignification processes to isolate cellulose, establishing it as a viable and sustainable raw material. This research aims to address both the management of invasive species, and the environmental consequences associated with *Salvinia molesta*, transforming it into a valuable resource for conventional cellulose production. Potential applications of this research encompass fields such as biomedical engineering, renewable energy, and various other domains.

2. METHODOLOGY

2.1 De-waxing

Salvinia was thoroughly washed with both tap water and distilled water to remove soil, sand and debris. It was then dried for 3 to 5 days. After drying, Salvinia was crushed into a fine powder using a grinder. A weighed amount of 30 grams of this powder was placed in a porous thimble. Next, a mixture of 300 ml of toluene and 150 ml of ethanol (in a 2:1 ratio) was prepared, and the crushed salvinia powder was extracted using the Soxhlet method for 6 hours (Sofla et al. 2016). After being dewaxed, the powder was neutralized by washing it in ethanol. Then, the dewaxed powder was dried for two hours at 60°C in an oven.

2.2 Alkali treatment

The dewaxed powder was treated with 2 (wt%) and 5 (wt%) potassium hydroxide for 2 hours at 90 centigrade while being continuously agitated in a magnetic stirrer (Chen et al. 2011). The process was repeated twice for each concentration (wt%). The ratio of the dewaxed sample to the alkaline treatment solution was 1:20 (g/ml). The sample underwent many rinses in distilled water to attain pH neutrality following each treatment. In this step, hemicellulose and a portion of lignin of the fiber, targeting non-cellulosic polysaccharides were removed.

2.3 Bleaching process

Following the alkaline treatment, the dried sample was bleached using 50 (wt%) hydrogen peroxide (H_2O_2) as described by Sun et al. (2000). The sample-to-solvent ratio in use was 1:20 (g/ml). The procedure was carried out twice in a magnetic stirrer at 90°C for two hours while swirling continuously. During each step of the bleach treatment, the sample was neutralized by washing it with distilled water. The sample was then dried in an oven at 60°C for two hours. Once dried, the cellulose was stored in an airtight bottle for storage. This step also removed residual lignin, resulting in cellulose with improved purity and whiteness of the cellulose.

2.4 Characterization

2.4.1 Fourier transform infrared spectroscopy (FTIR)

The FTIR spectra of *Salvinia molesta* was recorded under ambient conditions using a Bruker ALPHA spectrometer (Bruker Corporation, Billerica, MA) following chemical treatment. For sample preparation, the material was finely ground and mixed with KBr at a 1:100 (w/w) ratio and pressed into clear pellets. The spectra were obtained from a total of 24 scans at a resolution of 4 cm^{-1} covering the range of 4000-600 cm^{-1} r in transmittance mode.

2.4.2 Scanning Electron Microscopy (SEM)

The structural alterations, morphological structure, and surface properties of the materials were examined by scanning electron microscopy analysis (EVO 18, Carl Zeiss AG, Germany). An accelerating voltage of 15 kV was used to evaluate samples that had been coated with gold sputter.

3. RESULTS AND DISCUSSION

3.1 Analysis of Fourier Transform Infrared Spectroscopy (FTIR)

The FTIR spectral analysis of cellulose extracted from *Salvinia molesta as* shown in Fig.1 revealed significant peaks corresponding to various chemical functionalities. A notable peak observed between 3500 and 3000 cm^{-1} was associated with the sharp free O-H stretching vibration, attributed to aliphatic alcohols and absorbed water present in hemicellulose, cellulose, and other extractive components. Concurrently, absorptions in the 3000 to 2800 cm^{-1} range were attributed to C-H stretching vibrations while C-O stretching vibrations of the C- O- C ether group appeared between 1270 and 1050 cm^{-1}. The intensity of the peak at 1060 cm^{-1}, corresponding to the C-O stretch and alcohol structure, increased gradually from raw *Salvinia molesta* to bleached samples after chemical treatments. This increase indicates enhanced cellulose content (Hussain et al. 2016).
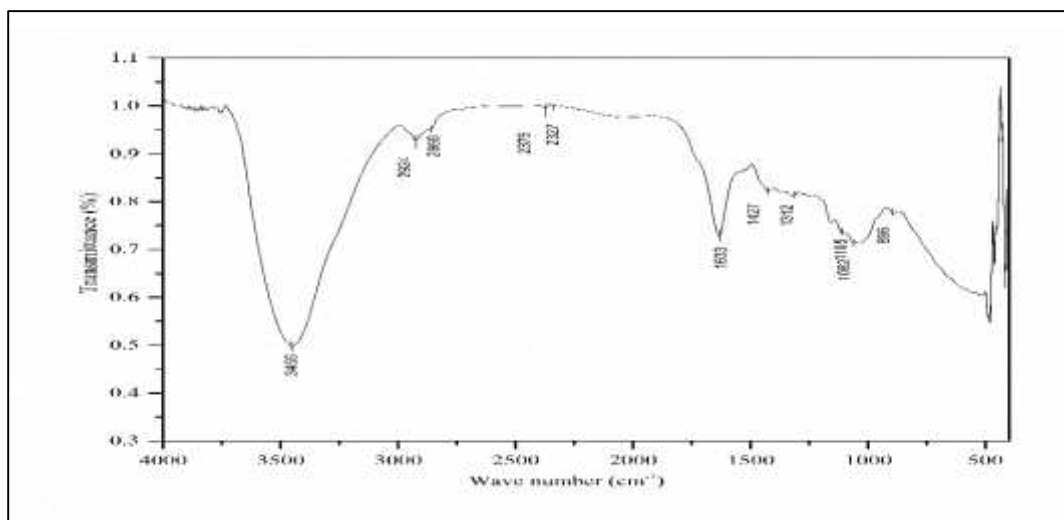
Fig. 1. Fourier transform infrared spectroscopy (FTIR) spectrum of extracted cellulose sample

Moreover, spectral patterns in the range from 3000 to 2850 cm^{-1} attributed to C-H stretching of alkenes and aromatics, were observed. The appearance of a peak around 2000 cm^{-1} suggested the presence of triple bond groups, including weak H-C bending. Ester's presence was indicated by significant C-O band absorption peaks between 1300 and 1000 cm^{-1}. A consistent peak at around 1630 cm^{-1}, attributed to O-H bending from absorbed water, was observed across all extraction stages (Asrofi et al. 2018). Additionally, peaks at 1370 cm^{-1} and 1420 cm^{-1} were attributed to C-H bending and CH_2 bending of the pyranose ring, respectively. Notable vibrations at 1030 cm^{-1} highlighted C-O-C pyranose ring vibrations in bleached samples after chemical treatments.(Ratnakumar et al. 2020). Furthermore, the characteristic peak around 890 cm^{-1}, indicative of the β-glycosidic linkage between glucose units in cellulose, was observed in bleached samples. These spectral findings offer valuable insights into the chemical composition and structural changes that occur during the cellulose extraction process from *Salvinia molesta.*

3.2 Analysis of Scanning Electron Microscopy

The SEM image of extracted cellulose from the *Salvinia molesta* sample shown in Fig. 2 is magnified at 5.00 KX. It reveals a clear network of thin, crisscrossing fibrils indicating the successful separation of cellulose microfibrils. The fibrous structure exhibits a smooth surface texture and a generally uniform distribution, suggesting the effective removal of lignin, hemicellulose, and other non-cellulosic components during the bleaching treatment. There are no obvious leftover materials or large agglomerates, indicating the successful elimination of contaminants. Instead, the presence of thin, continuous fibers with minimal surface roughness indicates a high degree of cellulose purity. Further, evidence of the structural integrity of the cellulose fibers can be seen in the folds or

undulations on the fiber surfaces which is important for applications requiring strong mechanical strength and stability.
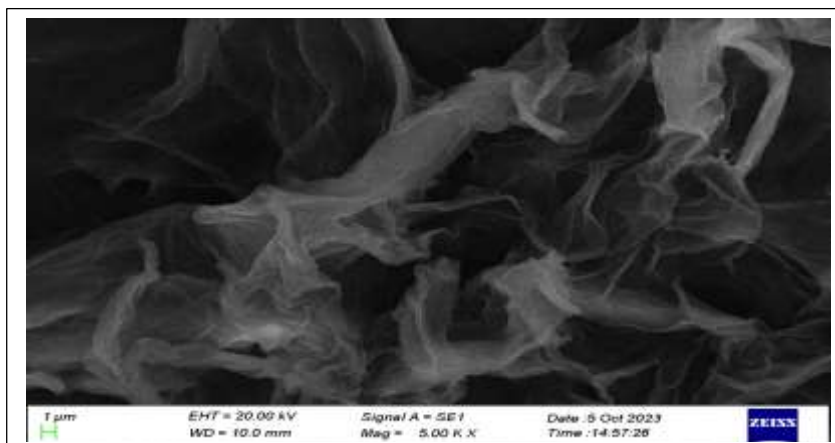
Fig. 2. Scanning Electron Microscopy (SEM) of extracted cellulose of Salvinia molesta sample

Previous research (Sun et al. 2000; Li et al. 2007) has shown that chemical treatments such as bleaching and alkaline processes effectively separate cellulose by eliminating lignin and hemicellulose. These findings align with the current results. In addition to having a smooth surface and no particle matter, the well-preserved shape of the fibers is in line with what is expected of high-purity cellulose made from plant materials using similar pretreatment techniques. *Salvinia molesta* has the potential to yield high-quality cellulose suitable for a variety of applications, and the SEM image provides overall confirmation that the pretreatment methods employed were effective in achieving this.

4. CONCLUSIONS

In conclusion, this study successfully demonstrates the extraction of high-purity cellulose from *Salvinia molesta* using a systematic chemical process. FTIR and SEM analyses confirm the progressive removal of lignin, hemicellulose, and wax, underscoring the material's structural integrity and purity. The findings emphasize *Salvinia molesta's* potential as a sustainable, low-cost feedstock for applications in bio composites, biodegradable packaging, and pharmaceutical carriers. Future research could focus on optimizing extraction methods, assessing scalability, and exploring functional modifications to tailor these cellulose fibers for specific industrial applications. This work opens pathways for managing invasive species while advancing sustainable materials science.

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USE OF COIR FIBRE-REINFORCED NATURAL RUBBER COMPOSITES FOR ROOFING INSULATION: A REVIEW

W. S. A. Sudarshana[1*], L. K. T. Srimal[2], and R. Gallage[3]
[1]Institute of Technology University of Moratuwa, Sri Lanka
[2,3]University of Ruhuna, Sri Lanka
asankas@itum.mrt.ac.lk[1*], srimal@mme.ruh.ac.lk[2], rgallage@mme.ruh.ac.lk[2]

ABSTRACT: In a building, most energy is consumed for the heating, ventilation, and air conditioning (HVAC) process. In this process, the thermal comfort in the building is maintained in a way that is comfortable for the people inside the building. The roof of a building plays a critical role in the building's overall energy efficiency and thermal comfort. Compared to walls, the roof is directly exposed to the sun, making it a major source of heat gain. Therefore, adding an insulation layer to the roof can help control a percentage of the heat entering the building and reduce the energy spent on HVAC systems. As a solution, researchers have been searching for sustainable insulation materials. These materials are becoming popular because they are biodegradable, non-toxic, and have significantly low embodied energy during manufacturing. These types of sustainable insulation materials are typically produced by using lignocellulose fiber. Coir fiber is one of the lignocellulose fibers derived from coconut husk and is a renewable, abundant, and environmentally friendly raw material for manufacturing composites. Polymeric composites reinforced with natural fibers such as coir fiber have been developed in recent years and exhibit significant potential for various engineering applications due to their sustainability, low cost, low weight, low thermal conductivity and mechanical strength. However, adding a binder material such as natural rubber to the coir fiber is essential to create the final material. Then, the final composite material will be fully biodegradable. This research work provides an overview of current information on coir fiber and coir fiber reinforced natural rubber composites. The manufacturing of various matrices reinforced with coir fiber and the physical, mechanical, and thermal properties of these composites have been studied by several researchers and included in this review. With the help of these details, a research gap has been identified to optimize the porosity of the natural rubber composite with coir fiber reinforcement to preserve its strength and mechanical properties while minimizing thermal characteristics.

Keywords: coir fiber, composite material, natural rubber, roofing insulation, thermal conductivity

1. INTRODUCTION

One of the main problems the future construction field may encounter is increasing energy consumption, especially in every phase, from design to demolishing. At present, one-third of the energy generated worldwide is used for buildings, with the highest percentage of this energy for Heating, Ventilation, and Air-Conditioning (HVAC) systems. Countries near the equator, such as Sri Lanka, typically receive much solar radiation. Therefore, most heat transfer happens through the building envelope, while the roof becomes the central part (Mintorogo et al., 2015). Thus, the building's indoor heat can be mainly reduced by insulating the roof using some material and reducing the cost of the HVAC systems. It is essential to use modern, sustainable, and environmentally friendly thermal insulation materials to reduce the buildings' carbon footprint (Walbrück et al., 2021). Many thermal insulation material types are available in the European market: 60% of them are mineral and inorganic, such as glass, stone, and wool; 30% of the materials are organic foam materials, such as expanded polystyrene, extruded polystyrene, and polyurethane. Only 10% are combined (wool, gypsum foam) and technologically advanced materials such as nano-cellular-foams or transparent materials (Pavel & Blagoeva, 2018).

A composite material is created using two or more material types, and the characteristics of the final product are always different from the individual materials used (Mahmud et al., 2023). When the coir fiber is used as a reinforcement material, the final material has better mechanical, physical, and thermal properties (Chamath et al., 2022, 2023). Coir fiber has some unique characteristics, such as resistance to seawater, microbial attack, and high impact (Mahmud et al., 2023). Besides, low thermal conductivity or high thermal insulating properties are important (Chamath, 2022). Composites made using natural rubber and coir fiber have become more popular. This natural coir/rubber composite has an exceptional property called *biodegradability* (Rachmawati &

Widiarini, 2021). This is important because non-biodegradable materials such as plastic have become a disaster for the environment. These plastic materials create numerous problems, such as blocking drainages, polluting oceans, reducing the strength and quality of soil, and causing greenhouse effect. Therefore, all materials used must be biodegradable to become an environmentally friendly composite. These biodegradable materials can be degraded using biological components such as bacteria and fungi (Gross & Kalra, 2002). If a composite material contains one or more bio or natural components, it is called a *bio-composite*. A bio-composite can be fully degradable or partially degradable, according to the materials it contains. For example, coir fiber-reinforced natural rubber bio-composite can be named a fully degradable bio-composite because both materials are biodegradable. Roof thermal insulation was noted many years ago because nearly 60% of the heat energy transferring happens across the roof of the building (Sadineni et al., 2011). Roof insulation reduces room temperature and saves much energy. When using an air-conditioner to reduce room temperature and increase thermal comfort, the energy spending for air-conditioner could be decreased by installing a roof thermal insulation. Thermal insulation can also be a transmitting barrier. It can be named as a radiant-transmitting barrier by adding a material such as aluminum foil from behind the roof thermal insulator. Therefore, the infrared radiation is reflected by a roof thermal insulator. Polystyrene, fiberglass, and rock wool/mineral wool are the most used roof thermal insulators in the Middle East and Asian countries. A roof with a polystyrene or polyurethane insulation layer can reduce over 50% of the heat load compared to a roof with no thermal insulation material installed (Sadineni et al., 2011). This review aims to find coir fiber reinforced natural rubber composite insulation materials that can address the growing demand for energy-efficient and environmentally friendly building solutions. By exploring the use of natural fibers like coir and their composites, this paper provides an analysis of their potential as viable alternatives to traditional insulation materials.

2. LITERATURE REVIEW

2.1 Properties of coir fiber

It is imperative to discuss how the coir fiber properties affect roofing insulation applications. Coir fiber has an excellent strength-to-weight ratio, which means they are lightweight and strong. Therefore, coir fiber has become an efficient and effective reinforcement material. Moisture resistance is another outstanding property of coir fiber. This property is very useful in roofing insulation applications because it helps prevent water damage and leakages (Chamath et al., 2022, 2023), thus reducing energy consumption by regulating the temperature. Another critical feature of coir fiber for roofing insulation applications is resistance to microbial attacks. Microbial degradation is minimized when the roof is insulated using coir mats made from coir fiber. In addition, roofing insulation promotes long term durability and performance. Besides these properties, coir fiber is an eco-friendly and sustainable material. Therefore, coir fiber contributes to a building's overall environmental sustainability. This discourages the use of non-renewable materials for thermal insulation. Harmful chemicals are not used when producing coir mats using coir fiber-reinforced natural rubber, and the manufacturing process is not harmful either. This non-toxic and environmentally friendly process is vital, especially in roofing applications. However, when manufacturing coir mats for roofing insulation, it is essential to modify the mats' surface to make them chemically moisture resistant. This modification can be done by applying an appropriate coating or doing some treatments while enhancing the moisture resistance (Chamath et al., 2020). Therefore, introducing coir fiber for roofing materials gives excellent physical and mechanical properties with more environmental benefits. Coir fiber is obtained from the coconut husks and shells, which are usually considered waste products of coconut cultivation. Therefore, coir fiber made of these by-products reduces waste and helps in creating more sustainable and eco-friendly constructions. Coir fiber is more cost-effective than other traditional reinforcement materials.

2.2 Coir fiber reinforced natural rubber composites

When a porous composite material such as coir fiber reinforced natural rubber composites is exposed to a thermal gradient, heat transfer happens through vibrational conduction in the solid phase, conduction by colliding gas molecules in the pore phase and radiation, either through a partially transparent solid phase or across large pores. For pore sizes smaller than 5 mm (about 0.2 in), convection heat transfer can be ignored for the material under consideration in this investigation. Therefore, the thermal conductivity of coir fiber-reinforced natural rubber composites, commonly used in roofing insulation applications, can be significantly reduced by incorporating porous materials. This is achieved by increasing the material porosity and using longer coir fibers. With longer coir fibers, the material has a prominent presence of air-filled cavities, which reduces the overall thermal conductivity. The porosity of the natural rubber composite with coir fiber reinforcement must be optimized to preserve its strength and mechanical properties while minimizing thermal characteristics. This balance can be established by conducting experiments and testing to measure the thermal conductivity and mechanical properties of the coir fiber-reinforced natural rubber composite with different fiber lengths. A detailed investigation into the porosity optimization of the composite is essential to achieve the desired mechanical strength while simultaneously minimizing thermal conductivity. Optimizing the porosity of the composite material can be achieved by implementing various techniques, such as controlling the volume fraction and arrangement of coir fiber reinforcement within the natural rubber matrix during the manufacturing process. Post-processing methods such as heat treatment or surface modifications could also be investigated to fine-tune the composite porosity. Optimizing the porosity of the coir fiber-reinforced natural rubber composite is integral in ensuring that the material meets the thermal insulation requirements for roofing applications while maintaining its structural integrity. By addressing the porosity factor, the composite can effectively achieve the desired balance between mechanical strength, thermal performance, and energy efficiency, thus enhancing its suitability for sustainable and environmentally friendly roofing insulation solutions.

2.3 Manufacturing of coir fiber polymer composites

Optimizing the composite's manufacturing process is necessary to ensure that coir fiber is properly distributed and aligned. The focus has been on implementing Vacuum-Assisted Resin Transfer Molding (VARTM) to enhance control over the resin infusion process and achieve a uniform distribution of natural rubber matrix within the coir fiber reinforcement. Manufacturing coir fiber-reinforced natural rubber latex composites addresses the difficulties faced in current manufacturing methods for coir fiber-reinforced materials, including insufficient resin distribution and limited fiber-matrix interaction. The mechanical and thermal properties of these composites depend on volume fraction and arrangement of coir fiber reinforcement within a natural rubber matrix. The primary intention of this study is to analyze the mechanical and thermal properties of the developed composite material as a roofing insulator for residential buildings. Several methods can be employed to optimize the porosity of the coir fiber-reinforced natural rubber latex composite manufactured by VARTM. These may include adjusting the vacuum level during the resin infusion process, exploring different molding pressures, and introducing innovative surface treatments to regulate the porosity at a micro level. These methods help ensure the composite maintains its structural integrity while achieving the desired thermal insulation properties essential for roofing applications.

2.4 Potential applications of coir fiber composites

One potential application of coir fiber composites is in noise-reducing materials. The natural acoustic damping properties of coir fiber can be used to build soundproofing and acoustic insulation products, such as partitions, wall panels, and ceiling tiles, contributing to the improvement of indoor environmental quality and the reduction of noise pollution. Another potential application lies in the development of ebonite rubber, a type of hard rubber used for various industrial and commercial

applications. The incorporation of coir fiber into rubber compounds can improve the mechanical properties, such as tensile strength and impact resistance, making the resulting material suitable for applications such as automotive components, sports equipment, and industrial machinery parts. Additionally, the use of coir fiber as a filler in natural rubber compounds has demonstrated potential for property development, enhancing characteristics like tensile strength, tear resistance, and hardness (Rachmawati & Widiarini, 2021).

2.5 Knowledge gap

The next research phase involves conducting experiments to validate the effectiveness of the identified methods for porosity optimization. This experimental validation will provide crucial data on the composite's mechanical strength, thermal conductivity, and insulation performance, further contributing to developing a sustainable and energy-efficient roofing material. Implementing these methodologies for porosity optimization will significantly enhance the composite's suitability for roofing insulation applications, addressing the industry's needs for environmentally friendly and high-performance materials. The research aims to improve the production process of coir fiber-reinforced natural rubber composites using VARTM and evaluate the thermal properties of the composite for roofing insulation applications. A study must examine the influence of coir fiber length on the effectiveness of reducing thermal conductivity in coir fiber-reinforced natural rubber composites, particularly for roofing insulation for buildings. The expected results include an enhanced production method for creating a natural bio-composite material. The importance of this research lies in its potential to generate a sustainable, environmentally friendly, and bio-degradable composite.

3. CONCLUSION

In conclusion, the coir fiber-reinforced natural rubber composite manufacturing process using VARTM offers a sustainable and eco-friendly alternative to traditional composite materials. The remaining work includes research on novel VARTM techniques, exploration of coir fiber reinforced natural rubber composites' mechanical and thermal properties for roofing insulation applications in buildings, and publishing in recognized conferences.

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AMOXICILLIN REMOVAL FROM WASTEWATER USING SRI LANKAN ACTIVATED CARBON: A KINETICS STUDY

M. D. A. S. Manchanayake[1], B. M. W. P. K. Amarasinghe[2], and G. K. Jayatunga[3]

[1,2] Department of Chemical and Process Engineering, University of Moratuwa, Sri Lanka.
[3] Institiute of Technology University of Moratuwa, Sri Lanka
ayeshamanchanayake@gmail.com[1*], padma@uom.lk[2], gayanij@itum.mrt.ac.lk[3]

ABSTRACT: This research explores the kinetics of amoxicillin adsorption using activated carbon produced from Sri Lankan coconut shells. Batch adsorption experiments were performed, and the obtained data were analyzed using various kinetic models, including the pseudo-first-order, pseudo-second-order, liquid film diffusion, and intra-particle diffusion models. Among these, the pseudo-second-order model provided the best fit, indicating that chemisorption is the dominant mechanism. The results demonstrated that increasing the adsorbent dosage enhances the adsorption efficiency. Furthermore, the intra-particle diffusion model revealed a lower rate constant during the later phase, indicating that the adsorption rate significantly slows down at this stage. This suggests that intra-particle diffusion acts as the rate-limiting step. In contrast, the liquid film diffusion model presented a poor fitting, indicating external mass transfer resistance insignificantly affecting the adsorption process. These results provide the necessary hints toward optimizing water treatment processes related to the removal of such antibiotics as amoxicillin

Keywords: activated carbon, adsorption, Amoxicillin, kinetic model

1. INTRODUCTION

Antibiotics are essential drugs used for the treatment of bacterial infections. However, their wide application has raised concerns about environmental pollution and related health impacts. Pharmaceuticals enter wastewater from a range of sources, such as healthcare facilities, pharmaceutical manufacturing processes, and residential use, thus contaminating natural water sources like rivers and lakes and, unfortunately, even drinking water (Khan *et al.*, 2020). Such pollution exacerbates the global crisis of antibiotic resistance through the selection and spread of antibiotic-resistant bacteria and related resistance genes (Muteeb et al., 2023). Sri Lanka, being a developing country with rapid industrialization, is burdened by issues related to wastewater management and control of antibiotic pollution. Although the law prohibiting the sale of antibiotics without prescriptions has been in place since 1986, non-implementation has resulted in self-medication and inappropriate use of antibiotics by healthcare providers for diseases where antibiotic treatment is not indicated (Samaraweera *et al.*, 2019).

Various types of adsorbents are being used for a wide range of applications, including naturally available materials, treated materials like activated carbon, manufactured sorbents such as zeolites and polymeric resins, and agricultural or industrial by-products.(Jayathunga and Amarasinghe, 2009; Wang *et al.*, 2021) Activated carbon, characterized by its high surface area and significant adsorption capacity, has demonstrated efficacy in the removal of antibiotics from wastewater (Neolaka *et al.*, 2023). The material's porous configuration facilitates the adherence of antibiotics via weak Van der Waals interactions, with the degree of adsorption being affected by various parameters, including pH, temperature, and contact duration (Singh et al. 2022). A range of antibiotics, such as tetracyclines, ciprofloxacin, norfloxacin (Ahmed & Theydan, 2014), macrolides, and metronidazole (Ahmed & Theydan, 2013), has been effectively eliminated from wastewater through the utilization of activated carbon. Also, Zha et al. (2013) showed organobentonite's effectiveness in removing amoxicillin from wastewater. The rate of adsorption and the factors that influence the process were studied under adsorption kinetics. It focuses on understanding how adsorption behaves over time, including the initial adsorption rate, the time taken to reach equilibrium, and the factors that affect these rates. The study of adsorption kinetics is essential for the design and optimization of adsorption processes in a wide range of applications such as environmental remediation, chemical separation, etc. This study aims to analyze the kinetics of antibiotic adsorption onto activated carbon.

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2. METHODOLOGY

2.1 Materials

In this study, granular activated carbon (GAC) purchased from Haycarb PLC in Sri Lanka was utilized as the adsorbent. GAC has mean diameter of 1185 μm, a bulk density of 450 kg/m³, and a true density of 1720 kg/m³, which were measured. Additionally, the surface area is 683.14 m²/g, and the pore size is 2.28 nm (Amarasinghe, 2007). A synthetic solution of amoxicillin, using amoxicillin trihydrate powder with 99.7% purity provided by the State Pharmaceutical Manufacturing Corporation, Sri Lanka, was used as the adsorbate. The concentration of amoxicillin in the solution was measured at its maximum absorbance wavelength of 235 nm using a UV spectrophotometer (SP-UV-500DB).

2.2 Batch Experiment

Kinetic studies were performed using five different dosages, 4mg/L, 8mg/L, 12mg/L, 16mg/L and 20mg/L of activated carbon mixed with amoxicillin solution which has initial amoxicillin concentration 50 mg/L. Samples were collected at regular intervals, and the remaining amoxicillin concentration was measured to monitor the adsorption process. The experiments were conducted until the amoxicillin concentration stabilized.

2.3 Analytical Techniques

The adsorption amount of the activated carbon was calculated as Equation 1,

$$Q_e = (C_0 - C_e)\frac{v}{w} \tag{1}$$

The adsorption capacity, denoted by Q_e (mg/g), was determined using Equation 1, which incorporates the initial concentration C_0, equilibrium concentration C_e, solution volume v (L), and adsorbent mass w (g).

Four models were applied in analyzing the experimental data in studying the adsorption mechanism: The pseudo-first-order adsorption kinetics are modeled using Equation 2, which assumes that the rate of adsorption is proportional to the difference between the equilibrium adsorption capacity and the amount of adsorbate remaining at time t. The pseudo-second-order kinetic model, as outlined in Equation 3, is used to describe chemisorption processes, where the adsorption rate depends on the availability of active sites on the adsorbent. The intra-particle diffusion model, depicted in Equation 4, considers the diffusion of the adsorbate into the pores of the adsorbent as a rate-limiting step during the adsorption process. The liquid film diffusion model is represented by Equation 5, which suggests that adsorption is influenced by the movement of the adsorbate through a boundary layer or film around the adsorbent particles.

$$ln(Q_e - Q) = -k_1 t + ln\, Q_e \tag{2}$$

$$\frac{t}{Q} = \frac{t}{Q_e} + \frac{1}{k_2 Q_e^2} \tag{3}$$

$$Q = K_i t^{0.5} + C \tag{4}$$

$$ln(1 - \frac{Q}{Q_e}) = k_{fd} t \tag{5}$$

Where, k_1 (min^{-1}) is the rate constant of pseudo first- order kinetic model; k_2 (g/(mg·min)) is the rate constant of pseudo-second-order kinetic model; k_i (mg/(g·min$^{0.5}$)) is the intra particle diffusion rate constant; and k_{fd} is rate constant for liquid film diffusion model.

3. RESULTS AND DISCUSSION

The experimental data were analyzed using both the pseudo-first order (Equation 2) and pseudo-second order (Equation 3) adsorption models. The strong correlation shown in Fig. 1 and Fig. 2 highlights the applicability of these models.
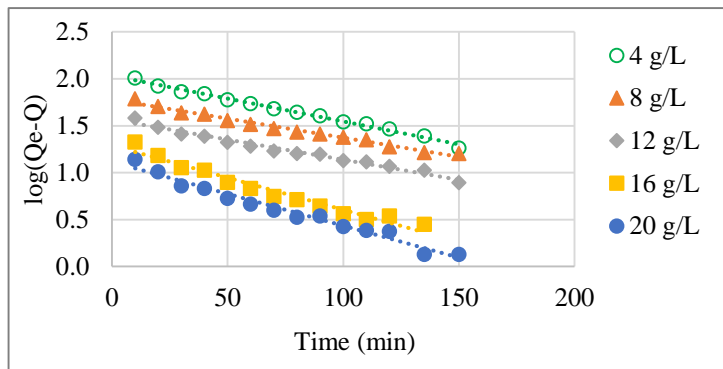
Fig.1. First order kinetic plot for amoxicillin adsorption on to activated carbon
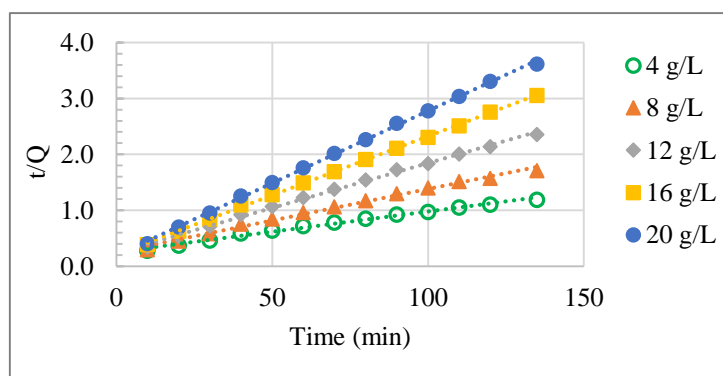
Fig. 2. Second-order kinetic plot for amoxicillin adsorption onto activated carbon

The kinetic parameters for first- order and second-order adsorption of amoxicillin onto activated carbon are summarized in Table 1.

Table 1. First order and second order kinetic parameters for amoxicillin adsorption

Activated carbon dosage (g/L)	First-order kinetic parameters		Second-order kinetic parameters	
	k_1 (l/min)	R^2	Rate constant k_2 (g/mg.min)	R^2
4	0.0049	0.9921	0.0002	0.9902
8	0.0041	0.9829	0.0005	0.9927
12	0.0043	0.9769	0.0011	0.9973
16	0.0068	0.9578	0.0021	0.9994
20	0.0068	0.9715	0.0034	0.9992

The plots indicate that the second-order kinetic model provides a better fit compared to the first-order model, which suggests that chemical adsorption plays a significant role in the adsorption process. "This chemisorption process involves the formation of chemical bonds between the amoxicillin molecules and the activated carbon surface, implying that both the concentration of the adsorbate and the number of active adsorption sites influence the rate of adsorption" (Moussavi *et al.*, 2013). Moussavi et al. also found that the adsorption of amoxicillin onto commercial activated carbon performed better under the pseudo second-order kinetic model.

Fig. 3 shows the outcomes when applying the intra-particle diffusion model (Equation 2.5) to the adsorption of amoxicillin onto activated carbon.
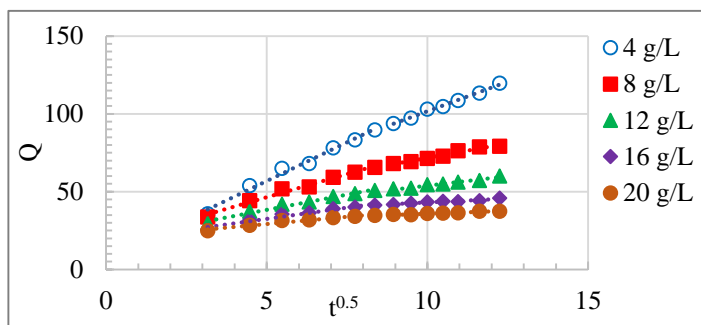
Fig. 3. Intra particle diffusion model for amoxicillin adsorption on to activated carbon

The parameters derived from the intra-particle diffusion model, as shown in Table 2, indicate that the diffusion rate decreases considerably in the later phase for all dosages of activated carbon. The lower intra-particle diffusion rate constant (k_{i2}) in the latter phase than the intra-particle diffusion rate constant for the initial phase (k_{i1}) suggests that this stage of the process is the rate-limiting step.

Table 2. The parameters of the intra-particle diffusion model for amoxicillin adsorption onto activated carbon

Activated carbon dosage (g/L)	K_{i1} (mg/g.min$^{0.5}$)	R^2	K_{i2} (mg/g.min$^{0.5}$)	R^2
4	9.9341	0.9848	7.6176	0.992
8	5.9671	0.9827	3.7542	0.9637
12	3.9035	0.9744	2.4246	0.9663
16	2.9006	0.9689	1.0349	0.8981

The data plotted for the liquid film diffusion model does not exhibit a strong fit. The low R^2 value shows that the mechanism of liquid film diffusion is not the dominant one controlling the adsorption process in this system. Smaller particle sizes and larger surface area of activated carbon can facilitate faster adsorption kinetics. Therefore, diffusion within the pores becomes the rate-limiting step rather than the diffusion across the boundary layer.

4. CONCLUSION

This study presents the adsorption kinetics of amoxicillin onto activated carbon from Sri Lankan coconut shells. Adsorption data were fitted to several models, with the pseudo-second-order model showing the best fit, indicating chemisorption as the primary mechanism. The intra-particle diffusion model suggests that diffusion within the particles is the rate-limiting step, with the adsorption rate decreasing in the later phase. In contrast, the liquid film diffusion model poorly fits, indicating that external mass transfer resistance is not a controlling factor. These findings highlight the role of intra-particle diffusion in improving amoxicillin removal from water using activated carbon.

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UTILIZATION OF VIRGIN COCONUT OIL FILTER SEDIMENT WASTE AS A SUSTAINABLE PLASTICIZER ALTERNATIVE TO AROMATIC OIL IN RUBBER COMPOUNDING

P. L. L. Arunodhi[1*] and H. D. S. Vishwa[2]

[1,2] Faculty of Computing and Technology, University of Kelaniya, Sri Lanka

arunodhiliyanage27@gmail.com[1*], deshan478@gmail.com[2], deshan478@gmail.com

ABSTRACT: Plasticizers are non-volatile chemicals with low molecular weights that enhance the flexibility and processability of polymers. In the rubber sector, plasticizers are typically derived from petroleum or mineral oil derivatives. One major disadvantage of petroleum-based oils is that they are a non-renewable resource. Additionally, mineral oils with high aromatic concentrations may possess carcinogenic properties. The ban on the consumption of polyaromatic oils has posed challenges for the oil and rubber research sectors in developing sustainable alternatives. The extracted virgin coconut oil is filtered through ugh plate and filter press. When using gravity filters, sediment may still settle at the bottom of the container over time. This waste is frequently discarded into the environment, but it can also be utilized depending on its content. This study focuses on using filter sediment waste as a replacement for aromatic oil rubber compounding. The mixing process involved a two- roll mill followed by vulcanization using the compression moulding method. Collected sediment waste (Moisture content < 3%) was used to replace aromatic oil dosage in increments of 0 %, 25 %, 50 %,75% and 100 % by weight percentage. The results revealed that this replacement led to reduction in physio-mechanical properties such as tensile strength, specific gravity, and elongation at break. Simultaneously, hardness, abrasion resistance, 300% modulus and tear strength showed an increasing trend. Careful formulation is necessary to optimize the level of filter sediment waste used as a plasticizer to achieve the desired properties of rubber compound. The rubber composite with 25 % weight replacement of sediment waste for aromatic oil exhibit significantly better performance. This can be due to the inherent properties of sediment waste which promotes greater compatibility with polymer base and aromatic oil. The newly identified 25% replacement can be applied during manufacturing applications offering commercial benefits while contributing to the reduction of aromatic oil usage and ensuring environment sustainability through the utilization of waste material.

Keywords: aromatic oil, plasticizer, sustainable, rubber compounding, virgin coconut oil

1. INTRODUCTION

Plasticizers are non-volatile chemicals with low molecular weights that enhance polymer flexibility and processability. (Nandanan, 2007) Petroleum-based oils are widely utilized in rubber compositions. Plasticizers for the rubber sector generally employed petroleum or mineral oil derivatives. (Cherubini et al., 2021) One major disadvantage of petroleum-based oils is that they are a non-renewable resource. Mineral oils with high aromatic concentration may have carcinogenic properties. (Petrovic et al., 1998, pp. 233–249). The ban on polyaromatic oil consumption has posed hurdles for the oil and rubber research area to develop sustainable alternatives (Cherubini et al., 2021). There are recent developments in the use of bio-based oils in elastomers. Bio-based oil is a new oil source that could replace petroleum oil in elastomers as a plasticizer. It is a low-cost, renewable alternative to petroleum plasticizers with numerous benefits. Bio-based oils typically include several functional groups and can be processed, changed, or polymerized for various uses (Li et al., 2017). Bio based waste cooking oils have been incorporated in elastomeric compounds as a substitute for conventional mineral oils (Cherubini et al., 2021). Coconut oil was employed as a plasticizer in a natural rubber compound, and its mechanical and thermal properties were compared to those of a control compound with naphthenic oil. (Nandanan, 2007). The extracted VCO is filtered through plate and frame filter press (Dharmaratne et al., 2016) When filtering with gravity filters, feet may still settle on the bottom of the container after a lengthy period of time; simply decant the VCO to another container, leaving the feet behind. (Bawalan and Chapman, 2006). This waste is frequently discarded to environment, but it can also be utilized for other purposes depending on the content. The research focusing on use of virgin coconut oil filter sediment waste as a replacement for Aromatic oil where systematically changed in increments of virgin coconut oil filter sediment 0%, 25% ,50% ,75% and 100% by weight percentage in rubber compounding formula (Table 1).

Physiomechanical properties of rubber composite such as Hardness, Tensile Strength, Elongation at break, specific gravity, 300% Modulus, Tear strength, Abrasion Resistance were tested. The practicality of applying natural-based plasticizer filter sediment waste was determined by comparing its attributes to the application of aromatic oil. Although previous research has explored the use of different alternative oils including coconut oil, no studies have specifically investigated the use of coconut oil filter sediment as a material. The research aims to provide fresh and sustainable insights into natural based waste as plasticizers could substitute petroleum oil in NR-SBR rubber compounding.

2. METHODOLOGY

Virgin coconut oil filter sediment waste were collected which are generated as result of filtration process during the virgin coconut oil production from Real oil mills (PVT) LTD. Collected fully homogenized Virgin coconut oil filter sediment waste were tested (at 105°C for 20 minutes) for the moisture content weight percentage whose value was <3% were used for compounding. A laboratory scale ban bury mixer (Protech industrial eng.co ltd CHSM 2.3,2.5HP) and two-roll mill (Protech industrial eng.co ltd CHSM 2.8,7.5HP) were used for blending the compounds. Rubber masticated for 4 minutes ~ 80°C in the Banbury mixture. Next fillers including plasticizers were added and mixed for 3-4 minutes. Finally, stearic acid, zinc oxide was added, and mixing was carried out for 6 minutes also temperature inside of the mixer indicated as 148°C at the end. After compound getting back to the room temperature compound mixture put into the open two roll mill. Accelerators, Vulcanizing agents were added to the compound. The compound was being mixed another 10 minutes approximately doing 5-8 mill passing. During this compounding process to get the uniform compounding and appropriate dispersion of the ingredients in the rubbery matrix proper nip cap and cuts were maintained Following that, the compositions were compressed moulded for 15 minutes at 150 °C. To ensure complete curing (100% cure), the cure time was set significantly higher than t95 (time to 95% cure). The t95 value was determined by measuring the increase in torque values of none-vulcanized rubber compounds and identify the time point where 95% of the maximum torque is reached. Mooney viscometer was used to measure the viscosity of rubber compounds at 100°C. Different test specimens were obtained after curing as moulded products all tests were conducted at 25°C.

Table 1. Sample formulation

Properties	Unit	Test method	A [Control] (0%)	B (25%)	C (50%)	D (75%)	E (100%)
HARDNESS	Shoe A	ISO - 868	49	50	51	51	52
SPECIFIC GRAVITY	---	---	1.163	1.17	1.185	1.183	1.18
TENSILE STRENGTH	MPa	ISO 37-2005	14.3	15	15.5	14.2	13.6
ELONGATION @ BREAK	%	ISO 37-2005	734	698	661	650	633
300% MODULUS	MPa	ISO 37-2005	1.8	2.2	2.4	2.5	2.7
TEAR STRENGTH [METHOD B]	N / mm	ISO 34-1 2010	36.1	32.3	29	28	31
ABRASION RESISTANCE	mm³	DIN 53516	245	286	320	345	367

3. RESULTS AND DISCUSSION

After 4 phr of coconut oil loading, the mechanical characteristics showed a significant improvement, resulting in good tensile strength of 18.26 MPa and elongation at break of 1859.05%. A crosslink density of 3.15×10^{-4} gm/mol/cm^3 was recorded (Othman and Ismail, 2020). The combination of the plasticizing effect and improved Carbon Black -Standard Malaysian Rubber 20 interaction influenced the Crude Palm Oil formulations' tensile characteristics, tear strength, hardness, and abrasion resistance (Abbas and Ong, 2009). Increasement of sediment waste can alter the distribution or efficacy of fillers, hence influencing hardness. The Fig. 1(a) shows the variation of hardness due to the replacement of Aromatic oil by sediment waste. It shows increasing trend of hardness in compounds with respect to the compound having 0% of sediment waste. The connection between hardness and plasticizer content in rubber compounds is usually inverse as plasticizer level increases, hardness decreases. This effect is critical for tailoring the mechanical characteristics of rubber to specific application requirements. The Fig. 1(b) shows the variation of specific gravity due to the replacement of Aromatic oil by sediment waste. It shows decreasing trend of hardness in compounds with respect to the compound having 0% of sediment waste. Sediment waste softens the rubber compound, increasing the free volume and decreasing the tight packing of polymer molecules. This greater free volume may reduce the overall density of the material, resulting in a lower specific gravity

Table 2. Test results

Material	A (0%)	B (25%)	C (50%)	D (75%)	E (100%)
NR	75	75	75	75	75
SBR	25	25	25	25	25
Aromatic Oil	5	5	5	5	5
Virgin oil filter sediment	-	1.25	2.5	3.75	5
clay	50	50	50	50	50
Stearic acid	1	1	1	1	1
Zinc Oxide	2.5	2.5	2.5	2.5	2.5
PEG 4000	1	1	1	1	1
TBBS	0.2	0.2	0.2	0.2	0.2
DPG	1.5	1.5	1.5	1.5	1.5
Sulfur	5	5	5	5	5

As per the Fig. 1(c) sediment can increase tensile strength, excessive amounts can reduce tensile characteristics. This is because excessive sediment waste can disrupt the polymer network, lowering the overall structural integrity of the material and resulting in a mushy and weak composite. This produces a softer, more ductile material that can stretch further but may fail under lesser stress. Graphical representation of Test results as shown in the Fig. 1(e), increased sediment waste in rubber compounds diminishes elongation at break by disrupting the polymer network, lowering cohesion, and weakening the material. Excess plasticizer causes softness, phase separation, and structural weakening rather than increasing flexibility. According to the Fig. 1(f), increasement of sediment waste may raise modulus by 300%. This is especially true when the sediment waste improves filler dispersion, increases polymer-filler interactions, or optimizes crosslink density. However, as sediment waste is a solid it may contribute for the rigidity of compound. The Fig, 1(g) shows the variation of tear tearing strength due to the replacement of Aromatic oil by sediment waste. Increased sediment waste content in rubber compounds diminishes tear strength because it weakens the polymer network by increasing chain mobility and resulting in a softer material.

Fig. 1. Graphical representation of Test Results

This allows cracks or tears to spread more easily into the rubber, resulting in lesser tearing resistance. As shown in the image 4.0 Increasing sediment waste content can improve abrasion resistance by increasing the flexibility allowing the material to withstand wear. Increased filler dispersion and smoother surface characteristics lead to improved performance. Replacement of Aromatic oil by Sediment waste has shown growth of abrasion resistance of rubber compound.

4. CONCLUSION

When use of Coconut Oil as Plasticiser in Natural Rubber Compounds they outperformed the compounds based on naphthenic oil in terms of tensile strength, rip strength, resilience, and abrasion resistance. The crosslink density of the coconut oil mixtures was similar to that of the reference substance. The crosslink density of the coconut oil mixtures was similar to that of the reference substance (Sunil, 2017). When its considered the overall performances of rubber composites which is included filter sediment waste as a plasticizer shows higher values and increasing trend than that of aromatic oil as plasticizer in properties like hardness, abrasion resistance, 300% modulus and tear strength while lower values and decreasing trend than that of aromatic oil as plasticizer in properties like Tensile strength, specific gravity, Elongation at break. Careful formulation is necessary to optimize the filter sediment waste as plasticizer levels to get the desired properties of rubber compound of Aromatic oil as a plasticizer. According to data analysis results and future trends, the sample with 25% of Aromatic oil replacement of filter sediment waste significantly shows positive

feedback and composite can be utilized in moulded formulation as per the required properties. Further laboratory trials must be done ensure the sharp optimal amount of filter sediment waste to be added. The replacement of Aromatic oil by Virgin coconut oil filter sediment in rubber compounds initiation would be a better insight in the way of health concern and sustainable utilization of materials.

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A STUDY ON INCREASEING RECYCLED RUBBER CONTENT IN SOLID TYRE TREAD COMPOUNDS BY INCORPORATING BALLOON AND FOAM RUBBER WASTE

U. U. C. D. Chandrasena[1*], D. T. D. Weerathunga[2] and J. C. Jayawarna[3]
[1,3] LAUGFS Corporation (Rubber) Ltd, Sri Lanka
[2]University of Sri Jayewardenepura, Sri Lanka
cdevinda025@gmail.com[1*], dhammikaweerathunga@sjp.ac.lk[2], janadara@laugfs.lk[3]

ABSTRACT: The solid tyre and latex industries face significant economic and environmental challenges due to their reliance on virgin rubber and waste materials. This study examines the integration of recycled latex balloon and foam rubber waste into solid tyre tread compounds. The aim is to formulate a compound that optimizes the use of recycled materials while adhering to the quality standards required for solid tyres. The experimental design included a control formulation (Test 1) comprising only natural rubber, and a test formulation (Test 2) incorporating natural rubber mixed with reclaimed balloon waste at a 70:30 ratio. Further tests (Tests 3-6) introduced varying proportions of latex foam waste, starting from 10 phr and increasing in 5 phr increments up to 25 phr, to the Test 2. (Virgin to Recycled ratio T3- 64:36, T4-60:40, T5-58:42, T6-56:44). Results reveal that incorporating recycled latex affects cure characteristics and physical properties. Specifically, increased recycled latex content reduces cure and scorch time while enhancing the cure rate. Torque properties relatively remain stable. The addition of recycled latex foam waste improves rebound resilience but results in decreased tensile strength, modulus, elongation at break, tear strength, and hardness. Notably, the aging performance in terms of hardness and modulus is comparable to virgin rubber, whereas elongation at break, tensile strength, and tear strength show improvements over the virgin compound. In conclusion, a formulation with 70:30 ratio of natural rubber to balloon waste and 20 phr of latex foam waste meets acceptable quality levels though it reduces modulus and tensile strength. This offers a viable, cost-effective alternative for sustainable solid tire tread compounds, addressing high raw material costs and supporting recycling and sustainability goals.

Keywords: balloon waste, foam waste, recycled latex, solid-tire tread, sustainability

1. INTRODUCTION

In 2020, major rubber consumers included China, the USA, and Japan, with Thailand as the top natural rubber producer. Sri Lanka emerged as a key exporter of solid tyres, while the USA led in imports (Rodrigo 2021). The rubber industry in Sri Lanka has seen a shift in recent years, with a notable increase in local utilization of natural raw rubber for value-added products. According to the 2021 annual review by the Rubber Research Institute of Sri Lanka, raw rubber exports slightly declined from 15,766 tons in 2020 to 15,490 tons in 2021, while export earnings rose from Rs. 5.6 billion to Rs. 8.3 billion. This growth rise in waste generation. Waste rubber management various strategies are employed to handle discarded rubber materials. These strategies include recycling, reusing, recovering energy, and landfilling (Markl and Lackner 2020). Among these options, the predominant approach to waste rubber management is energy recovery. Rather than disposing waste rubber in landfills, which can contribute to environmental concerns (Ali Shah et al. 2013). Recycling and reusing rubber waste are essential for sustainability and reducing environmental impact. This thesis aims to develop a solid tire tread compound using recycled latex balloon and foam waste while maintaining quality standards, promoting sustainable tire production in Sri Lanka by addressing waste disposal and raw material costs.

2. METHODOLOGY

Preparation of latex foam waste, latex balloon waste, and solid tire tread compound latex foam waste was air-dried to a constant weight and then milled using an XKP-560 two roll rubber shredder, followed grinding to achieve fine crumbs, which were separated into 30-mesh sizes. Latex balloon waste was reclaimed through a mechanical and chemical process using a two-roll mill at 60–70°C with a 1:1.25 friction ratio and a 100:1 ratio of balloon waste to IPPD. For the solid tire tread compound, natural rubber was mixed with reclaimed balloon waste and ground latex foam waste on a two-roll mill, with increasing amounts of foam waste (5 to 25 phr) added in successive tests to evaluate the effects on the compound.

The experimental design included a control formulation (Test 1) comprising only natural rubber, and a test formulation (Test 2) incorporating natural rubber mixed with reclaimed balloon waste at a 70:30 ratio, as established by Jayawarna (2015). Further tests (Tests 3-6) introduced varying proportions of latex foam waste, starting from 10 phr and increasing in 5 phr increments up to 25 phr, to the Test 2. (Virgin to Recycled ratio T3- 64:36, T4-60:40, T5-58:42, T6-56:44). Three compound samples were prepared for each formulation, followed by characterization of each sample.

Characterization

The cure characteristics of the compound were analysed using an Oscillating Disk Rheometer (ODR) EKT-100H, which provided data on scorch time (TS2), 90% cure time (TC90), minimum torque (ML), and maximum torque (MH). Hardness was measured using a Shore A durometer following ASTM D2240 standards to assess indentation resistance. Modulus, tensile strength, and elongation at break were tested with a Gotech tensile testing machine (GT-7010-AEP) per ASTM D412, while tear strength was evaluated per ASTM D624. The DIN abrasion test, per ASTM D5963, measured abrasion resistance, and rebound resilience was tested using the GTKB18 according to ASTM D7121. Glass transition temperature (Tg) was measured using a Dynamic Mechanical Analyzer (PerkinElmer DMA 8000), and swelling tests were performed using the equilibrium swelling method in accordance with ASTM D471 standards.

3. RESULTS AND DISCUSSION

Properties of tire tread compound

Cure characteristics

Minimum torque (ML), maximum torque (MH), and the torque difference indicate the stock's viscosity and processability. Increasing amounts of latex foam waste raised the ML, as the filler restricts molecular movement. min-max torque values remained stable, indicating consistent crosslink density (Chuan and Siang 2017; Ismail, Nordin, and Noor 2002; Jayawarna 2015). Treating latex foam as a filler. Scorch time (TS2) and cure time (TC90) decreased with increased latex foam, indicating that unreacted curatives migrate into the rubber chains, affecting sulphur curing (Formela and Haponiuk 2014; Kim et al. 2007). Despite reduced scorch safety and cure time, which benefits production throughput. The lowest scorch safety achieved was 200 seconds, aligning with industry standards. T1 and T2 show no significant change in cure rate index, while T3 to T6, with ground latex foam waste, display an increasing trend. This suggests unreacted accelerators in the foam speed up curing without increasing crosslink density.
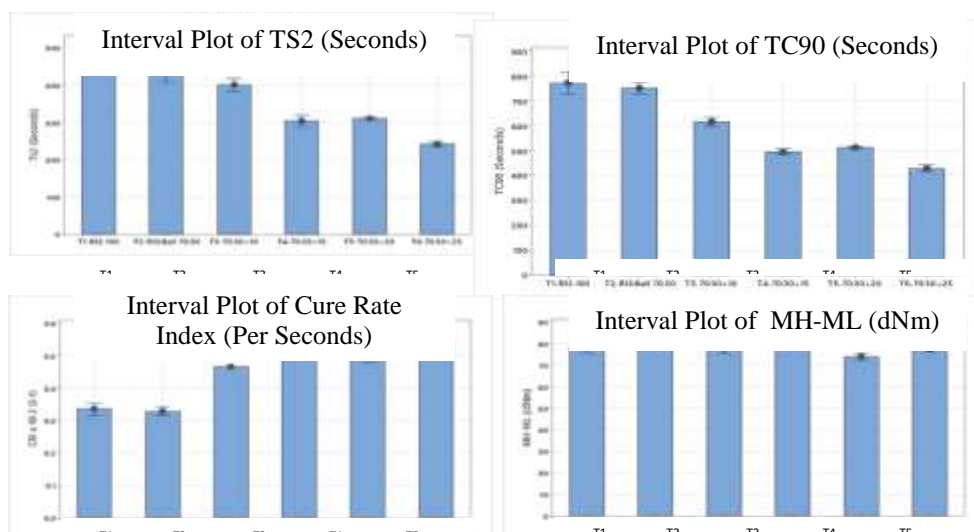
Fig. 1. Impact of Recycled Rubber Content on the Curing Characteristics of Solid Tire

Physico-mechanical properties

Evaluation of Tensile Strength, Tensile Modulus at 300% Elongation, Elongation at Break, and Tear Strength.

When compounded with ground latex foam waste, increasing foam content slightly reduces tensile strength due to weak bonding between foam particles and the natural rubber matrix, with agglomeration further weakening particle interactions (Fig. 2). Despite this, 90% of tensile strength is retained even with 25 phr foam (Ramarad et al. 2015; Sonnier et al. 2007; Sreeja and Kutty 2000). Modulus increases with reclaimed balloon waste (T2) but decreases as latex foam is added, reflecting reduced stiffness (Chuan and Siang 2017; Jayawarna 2015; Najib et al. 2011). Elongation at break and tear strength decrease with rising foam content, attributed to weak interfaces and crack propagation (Ismail et al. 2002), though tear strength stabilizes beyond a certain point (Chuan and Siang 2017), meeting industry standards for solid tire tread applications.
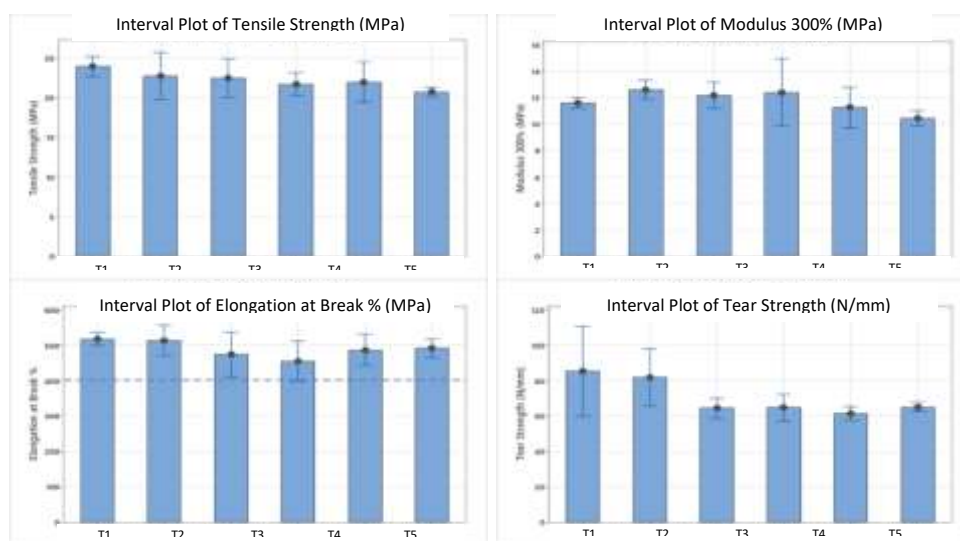
Fig. 2. Impact of Recycled Rubber Content on the Tensile Strength, Tensile Modulus at 300% Elongation, Elongation at Break, and Tear Strength.

Evaluation of Hardness, Rebound resilience, Abrasion resistance and Density:

The study examines the effects of adding reclaimed balloon waste and ground latex foam waste to solid tire tread compounds. Hardness increases slightly with the addition of reclaimed balloon waste (Chuan and Siang 2017; Jayawarna 2015) but decreases marginally with latex foam, remaining within acceptable industry standards and remained stable (Fig. 3). Rebound resilience improves by up to 6% due to the foam's microcellular structure (Dick 2014; Phiri et al. 2019), reducing energy loss and heat buildup. Abrasion resistance decreases with increased foam waste, though results remain acceptable for tire performance. The compound's density shows a slight increase with reclaimed balloon waste (Chuan and Siang 2017) but decreases as more ground latex foam is added due to its low-density properties.

Evaluation of Aging Properties, Measurement of swelling ratio & Glass transition temperature:

Aging properties of compounds are evaluated by measuring changes in hardness, tensile strength, elongation at break, and tear strength. The results indicate that hardness remains within a 6-8% range, with tensile strength retention being higher in compounds containing reclaimed balloon and latex foam waste compared to pure natural rubber (T1). Modulus variations do not exceed 40%, and elongation and tear strength improve across all test compounds. The swelling ratio remains consistent in T1 and T2 compounds, while T4 to T6 show an increase due to the foam's microcellular structure, which absorbs more toluene as foam waste content rises.

The crosslink density remains stable, with the increased swelling ratio resulting from the foam's absorption properties. The glass transition temperature (Tg), crucial for tire performance in cold

conditions, shifts from a flexible to a brittle state, affecting traction. The Tg of the T6 compound (with maximum filler load) is measured at -44.2°C, compared to -64.5°C for T1, demonstrating the impact of ground latex foam. Understanding Tg is key for assessing low-temperature behaviour and tire safety.

4. CONCLUSION

In conclusion, grinded latex foam waste can be effectively incorporated with latex balloon waste to manufacture natural rubber solid tire tread compounds. While cure and scorch times decrease with higher recycled content, the cure rate slightly increase. Min-max torque values and hardness remained stable, rebound resilience improves, but tensile strength, modulus, elongation at break, tear strength decrease. Aging performance shows that hardness and modulus remain stable, while tensile strength, elongation at break, and tear strength surpass virgin compounds. A 70:30 ratio of natural rubber to balloon waste with 20 phr of latex foam waste is a sustainable, cost-effective solution for solid tire tread production.

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EXPLORING CELLULOSE AND NANOCELLULOSE BASED MATERIALS FOR WATER PURIFICATION: A MINI REVIEW

W. W. Y. Sanjana[1] and D. Dahanayake[2*]

[1,2] Faculty of Science, NSBM Green University, Sri Lanka

wwysanjana@students.nsbm.ac.lk[1], damayanthi.d@nsbm.ac.lk[2*]

ABSTRACT: Cellulose and nanocellulose-based materials have emerged as promising candidates for water purification due to their abundance, biodegradability, and tunable properties. This review examines several materials made from cellulose, such as hydrogels, composites, and nanofibers, emphasizing their special functionalization techniques and structural characteristics that improve adsorption and filtering properties. We compare their performance indicators with traditional purification techniques to assess how effectively they remove contaminants such as heavy metals, organic pollutants, and infectious substances. Cellulose exhibits stiffness and a crystalline structure due to hydrogen bonding. Its basic state is compact, porous, and rich in binding sites, making it effective as a bio adsorbent. Cellulose modification techniques are divided into two categories: direct modifications (e.g., sulfation, etherification, and esterification) and polymerization methods (e.g., free radical, ring-opening) that graft monomers onto cellulose. The review also discusses issues with cellulose-based adsorbents' scalability, affordability, and regeneration. Nanocellulose has demonstrated significant effectiveness in water purification, with various modification techniques enhancing its performance. Nanocellulose, with its enhanced mechanical properties and unique nanoscale features, offers significant advantages over traditional cellulose, making it a promising material for a wide range of advanced applications particularly in water purification. Previous studies indicate that the preparation of composites from nanocellulose has yielded promising results in the treatment of contaminated water. The potential relevance of cellulose materials in sustainable water management practices is emphasized by discussing future perspectives on inventive fabrication techniques and their integration into current water treatment systems.

Keywords: water purification, cellulose, nanocellulose

1. INTRODUCTION

Water treatment is becoming a major global concern with the increasing need for safe and clean water (Werber *et al*., 2016). Novel materials and technologies are essential to solve the urgent problems of rising pollution, contamination, and resource scarcity (Coccia & Bontempi, 2023). Traditional water treatment methods to ensure safety and purification of water for various applications are coagulation (Kolya & Tripathy, 2013), filtration (Schelling *et al*., 2023), disinfection, adsorption (Ghorai *et al*., 2014), and membrane filtration. Traditional methods have their own set of strengths and limitations. Consequently, the development of contemporary water treatment methods has been greatly aided by the advancement of adsorption and membrane filtering technologies, guaranteeing the availability of safe and clean drinking water to populations across the globe. Polymers are crucial to the adsorption and membrane filtration processes of water treatment, as they improve performance. However, interest in bio-polymer-based adsorbents and membranes has increased due to issues regarding the biodegradability of synthetic polymers. Since bio-polymer-based adsorbents and membranes are environmentally friendly, they present an alluring substitute (Kolya, 2023). Additionally, bio polymeric nanocomposite materials have lately caught the interest of researchers, as they show promise for a variety of water treatment applications (Arif *et al*., 2019). These materials offer improved performance and efficiency by combining the benefits of biopolymers made from renewable resources with the special qualities of nanofillers. Since biopolymers are biocompatible, biodegradable, and versatile, they have various benefits in the water treatment industry (Romero-montero *et al*., 2023). This review explores the use of cellulose and nanocellulose, in water purification, along with their various modifications.

2. LITERATURE REVIEW

Cellulose

Cellulose is considered the highest abundant polymer on earth which compromises around 40-50% of the biomass (Abdelhamid, 2024). The 1,4 glucoside linkages bind the –D-glucopyranose residues that make up cellulose, a linear biopolymer (Al-Gethami *et al*., 2024). Numerous functional groups,

including hydroxyl groups, are present in cellulose and help contribute to its hydrophilic properties (Sharma, 2023). The functional groups on the surface of cellulose allow for the attachment of a variety of molecules (Lin *et al.*, 2012). Three hydroxyl groups (-OH) are found in cellulose units, which are anhydroglucose molecules, at carbons 2, 3, and 6. These hydroxyl groups provide the material with its stiffness and crystalline structure by forming intra- and intermolecular hydrogen bonds both inside and between the macromolecules. It must be at its most basic state, which is compact, porous, and rich in active binding sites for cellulose to function as a bio-adsorbent (Jyoti *et al.*, 2022). Cellulose modification techniques are primarily categorized into two main types. The first category involves direct modification methods, where functional groups such as sulfation (Rizkyana *et al.*, 2022), etherification (Ranjha *et al.*, 2023), carbanilation (Barthel & Heinze, 2006), silylation (Gupta *et al.*, 2023), esterification (Tang *et al.*, 2016), and amination (Azzam *et al.*, 2015) are attached directly to the hydroxyl groups of cellulose molecules.

The second category encompasses techniques such as free radical polymerization, ring-opening polymerization, and controlled radical polymerizations, which graft monomers onto cellulose chains either in homogeneous or heterogeneous solutions (Dalej *et al.*, 2022). These modified cellulose components play a crucial role in water purification and the removal of hazardous organic and metal contaminants (Sari *et al.*, 2023). Heavy metal ion adsorption on cellulose adsorbents can be facilitated through ion-exchange processes, where heavy metal ions are swapped with non-toxic ions like sodium (Na^+) or potassium (K^+). This method is specifically used for removing metal ions (Al-Gethami *et al.*, 2024). The materials can also be processed using them to create hydrogels and aerogels. The three-dimensional network materials known as hydrogels are composed of chains of polymers joined by physical or chemical interactions (Khan *et al.*, 2023). Chemical modifications such as crosslinking and grafting or physical (such as blending, inclusion, and filler addition) techniques can be used to modify cellulose hydrogels (Radoor *et al.*, 2024). The degree of cross-linking and the concentration of the polymers determine the mesh size, or precise size of the holes within each hydrogel (Khan *et al.*, 2023).

Hydrogels based on cellulose have been successfully developed to remove hazardous dyes, heavy metals, and other environmental contaminants (Radoor *et al.*, 2024). As amine groups are added, polyethyleneimine chemically bonds to oxidized cellulose hydrogels to improve their adsorption capabilities. Furthermore, adding 2-acrylamido-2-methylpropane sulfonic acid (AMPS), which creates sulfonic acid groups, to cellulose-based hydrogels improves their capacity to absorb cationic dyes and metal cations (Zhang *et al.*, 2023). The polymer chain's abundance of hydroxyl groups, which easily form hydrogen bonds, makes processing challenging and restricts the wider application of cellulose-based hydrogels. Additionally, the poor mechanical qualities and limited biocompatibility of these hydrogels limit their usefulness and recyclability in adsorption applications (Zhang *et al.*, 2023). Cellulose fibers must be altered to incorporate both positive and negative charges. Nucleus addition, affinity procedures, and electrophilic addition are some of the techniques used to accomplish this (Abdelhamid, 2024). Cellulose has a highly ordered and crystalline structure due to its strong hydrogen bonding, which renders it nearly insoluble in typical solvents. The potential applications of cellulose are limited by this attribute particularly those requiring its transformation into soluble or highly processable forms (Ai *et al.*, 2021).

Nanocellulose

Nanocellulose (NC) are cellulose that can be produced at nanoscale. Researchers explore nanocellulose due to its favorable physical and chemical properties. These include its natural availability, high strength, rigidity, renewable nature, ability to break down biologically, compatibility with living systems, and overall sustainability (Ma et *al.*, 2011). There are range of forms, including TEMPO-oxidized cellulose nanofibrils (TOCNF), bacterial nanocellulose (BNC), cellulose nanocrystals (CNC), enzymatically derived nanocellulose (ENC), and cellulose nanofibrils (CNF) (Sultan *et al.*, 2018).

The process of obtaining nanocellulose involves three main steps; pretreatment, removal of color and impurities through bleaching, and separation of the cellulose into nanoscale, respectively (Jali *et al*., 2024). Breaking down cellulose to the nanoscale solves important problems related to layered architectures and improves the antifouling capabilities of CNC membranes. Using CNCs, Huang et al. improved the water permeability and chlorine resistance of thin film composite nanofiltration membranes (Huang *et al*., 2019). The addition of CNCs to thin film composite (TFC) membranes resulted in a significant improvement in salt rejection showing 96.1% of $MgSO_4$ and 98.3% of Na_2SO_4 removal. Moreover, the water flux increased dramatically to 106.9 L m^{-2} h^{-1} as compared to TFC membranes without CNCs. In order to improve antifouling and separation efficiency, Bai et al. added cellulose nanocrystals to a polyamide (PA) layer while creating a thin film composite (TFC) membrane (Bai *et al*., 2018). The resulting CNC-TFC membranes showed a 60.0% improvement in permeability compared to TFC membranes without CNCs, with just 0.02 w/w % of CNCs. CNC-TFC membranes exhibit greater fouling resistance and recovery capabilities compared to conventional membranes, making them attractive options for desalination and water purification applications. Among various functionalization techniques, the carboxylation of nanocellulose for the uptake of cationic species has been the most extensively researched (Hasani *et al*., 2008). This approach offers the highest adsorption efficiency for a wide range of metallic cations and cationic dyes. Additionally, esterification with dicarboxylic acids or oxidation mediated by TEMPO can enhance the sorption of cationic species (Hasani *et al*., 2008).

The carboxylated CNCs produced using the TEMPO-oxidation method exhibited significantly better adsorption of methylene blue (769 mg/g at pH 9) compared to the sulfated CNCs, which only absorbed 118 mg/g at the same pH level (Batmaz *et al*., 2014). Carboxylated CNCs can alternatively be synthesized by esterifying surface hydroxyl groups with maleic anhydride. This method enhances the adsorption efficiency for various cationic dyes, including crystal violet, methylene blue, and malachite green. For instance, at pH 4, the maximum adsorption of crystal violet reached 244 mg/g (Qiao *et al*., 2015). When polymers with amino groups were grafted onto nanocellulose, they exhibited a markedly increased adsorption rate for various dyes. This improvement is attributed to the interactions between the dyes and the amino groups, especially the anionic dyes (Jin *et al*., 2015). In one approach to produce cationic CNCs, sodium periodate is used for oxidation, followed by a reaction with ethylenediamine. CNCs prepared using this method showed a maximum adsorption capacity of 556 mg/g for acid red GR dye. The adsorption performance of these cationic CNCs was affected by the pH-dependent behavior of the functional groups. Unlike CNCs with carboxyl groups, the amine groups in these cationic CNCs demonstrated peak adsorption at lower pH levels, with a decline in uptake capacity as the pH increased (Jin *et al*., 2015). When the cationic CNFs were produced through quaternization with glycidyltrimethyl ammonium chloride, it was found that the uptake capacity for Congo red was 664 mg/g and acid green 25 was 683 mg/g within a few seconds (Pei *et al*., 2013).

3. CONCLUSION

Due to their special structural qualities and adaptability, cellulose and its derivatives, including nanocellulose, have shown a great deal of promise in water purification applications. By employing diverse modification techniques, such as carboxylation and esterification, or sophisticated polymer grafting methods, these materials can be precisely tailored to improve their adsorption capabilities for pollutants like organic dyes and heavy metals. The continuous development of cellulose-based adsorbents reflects our increasing knowledge of their versatility and effectiveness in solving challenging problems related to water contamination. Further research and development into cellulose modifications will result in even more sustainable and effective water treatment

technologies, highlighting the critical role that these biopolymers play in pollution control and environmental management.

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A METHOD FOR IMPLEMENTING THE MECHANICAL PROPERTIES OF MALEIC ANHYDRIDE DERIVATE GRAFTED NATURAL RUBBER-CLAY NANOCOMPOSITE VULCANIZATE PREPARED FROM ACID FREE CO-COAGULATION TECHNIQUE

S. G. J Perera[1*], S. M. Egodage[2] and S. Walpalage[3]
[1] Institute of Technology, University of Moratuwa, Sri Lanka
[2,3] Department of Chemical and Process Engineering University of Moratuwa
Sudarshana79@gmail.com[1*], smegodage@gmail.com[2], walpalage.shantha@gmail.com[3]

ABSTRACT: Two types of nanocomposite vulcanizates, Nanocomposite A and Nanocomposite B, were successfully prepared from maleic anhydride derivative-grafted natural rubber latex (NRL). Bis(triethoxysilylpropyl) tetrasulfide (TESPT) grafted organoclay (OMMT-S) was incorporated at loadings of 2 and 5 phr. The coagulation of the rubber-clay mixture in an acid-free environment was expedited by employing two gelling agents: sodium dodecyl sulfate (NADS) and cetyl trimethyl ammonium bromide (CTAB). In comparison to the vulcanized control sample of un-modified un-filled NR prepared by the conventional method (Control-A), the addition of 5 phr OMMT-S to vulcanized grafted NR (B-5) resulted in a notable improvement in mechanical properties. Specifically, B-5 demonstrated an increase in tensile strength by 167%, a rise in modulus at 300% by 56%, and elongation at break enhancement by 36%.

Keywords: clay nanocomposite, natural rubber, NR grafting, rubber-filler interactions

1. INTRODUCTION

The co-coagulation method in absence of a co-coagulating agent like acid would be an alternative method to prepare NR-clay nanocomposites with retention of exfoliated clay structures during the destabilization of both clay and rubber which was also practiced in previous studies (Jayaraj et al., 2017; Jayaraj et al., 2018). In this method, destabilization would occur during oven drying, and therefore only water will be removed by evaporation without removing non-rubber substances. The speed up of co-coagulation is also vital to uniform dispersion of clay in rubber but it is difficult to obtain by traditional evaporation method. Use of organoclay by modification of Montmorillonite clay (MMT) with a long-chain cationic surfactant would facilitate further retention of exfoliated clay structures in the rubber phase and better tensile strength and elongation at break were obtained. Those properties were further improved in another study by grafting Bis(triethoxysilylpropyl) tetrasulfide (TESPT) coupling agent on to organoclay (Perera et al., 2020). However, neither of previous studies exhibited improved modulus at 300% elongation and tear strength, even though other mechanical properties were exhibited as a satisfactory level. Retaining exfoliated clay structures and strong interactions between rubber and clay is necessary to obtain better overall mechanical properties. Maleic Anhydride (MAH) Derivative-Grafted NR is suggested in current study to promote strong interaction with modified nanoclay to enhance mechanical properties.

2. METHODOLOGY

The dry rubber content (DRC) of centrifuged NRL was adjusted to 30% (w/w) with deionized water. Urea 0.1% (w/w), Sodium dodecyl sulfate 1% (w/w) and 0.025% (w/w) each of the solvents (acetone, ethanol, and isopropanol) were then mixed with the diluted NRL at 30 °C for 60 min. It was then centrifuged to obtain de-proteinized NRL having a DRC of 60% (w/w) according to the method described in the literature (Wongthong et al., 2013). Maleic Anhydride (MAH) was heated to its melting temperature, and it was mixed with 25 % (w/w) excess ammonia to obtain maleamic acid (MA) under isopropanol medium. It was dried at 50 °C for two hours in the oven to eliminate excess ammonia and isopropanol. It was then diluted with distilled water to prepare 12.5 % (w/w) maleamic acid solution. The de-proteinized NRL was stabilized by the addition of 10.0 % (w/w) NADS dispersion and transferred into a 500 ml reactor equipped with a reflux condenser, a mechanical stirrer, and a thermometer. Isopropanol and the MA solution were then added according

to the formulation given in Table 1. The mixture was stirred for 30 min under a nitrogen atmosphere to remove dissolved oxygen. Afterward, the mixture was heated up to 50 °C and homogenized dispersion of 10.0 % (w/w) TEPA and Cumene hydroperoxide (ROOR) were added. The mixture was then kept at the same temperature for 2 h to complete the grafting reaction of succinimide (SI) into NRL and is called SI-grafted NRL.

Table 1: Formulation of SI grafted NRL

Ingredient	Loading, in dry weight
60% (w/w) de-proteinized NRL	85 phr
12.5% (w/w) MA solution	15 phr
10% (w/w) NADS dispersion	1.3 phr
Isopropanol	7.6 pph
25% (w/w) TEPA dispersion	0.5 pph
25% (w/w) Cumene hydroperoxide	0.1 pph

Note: phr – parts per hundred parts of rubber; pph = parts per hundred parts of the organic component, which included both rubber content of the centrifuged latex and MA solution.

20 % (w/w) grafted deprotenized prepared NRL according to the Table 1 was blended with 80% (w/w) of centrifuged latex (60% DRC) to obtain the final NRL.

Different NRL-clay mixes and their controls were prepared using the mechanical stirrer operated at a speed of 60 rpm for 24 h, and 1 phr loading of NADS was added to each NR-clay mix and control, and mixing was continued under the same conditions for 15 min. After that, 2 phr loading of CTAB was mixed with each mix for gelling, and the nanocomposites and the controls were prepared by drying the gels in an air circulated oven at 50 °C for 48 h, according to the acid free co-coagulation method described in some studies (Jayaraj et al., 2017; Jayaraj et al., 2018; Perera et al., 2020).

Table 2. Formulations of NR-clay mixes and their controls

Ingredient	Control-A	A-2	A-5	Control-B	B-2	B-5
	Loading (dry basis), phr					
NRL	100	100	100	-	-	-
SI-grafted NRL	-	-	-	100	100	100
OMMT-S	-	2	5	-	2	5

Tensile properties such as tensile strength, elongation at break and modulus at 300% elongation (mod 300%) were measured using Hounsfield H10KT tensile tester as per ISO 37 and ISO 34-1, respectively.

3. RESULTS AND DISCUSSION

Fig. 1 shows stress-strain curves for the four nanocomposite vulcanizates and its controls. It is intriguing to observe that Control-A exhibits breakage at a lower tensile stress. The presence of assembled structures resulting from the addition of CTAB, NADS, and ZnO may create weak sites that are unable to withstand higher tensile stresses, leading to fractures even at minimal stress levels. This phenomenon is effectively regulated by the incorporation of clay layers and the modification of NR. In essence, the introduction of clay layers and modification prevents the formation of larger assembled structures, thus contributing to the improved strength of the material at higher stress. The

strain-induced crystallization of B-2 and B-5 nanocomposite vulcanizates is greater than that of A-2 and A-5 nanocomposite vulcanizates and may be due to improved rubber filler interactions. The effect is higher for B-5 nanocomposite vulcanizate than B-2 nanocomposite vulcanizate due to reinforcement effect by higher number of clay exfoliation. In general, when strain-induced crystallization is increased, elongation at break is reduced. Most interestingly, B-2 and B-5 nanocomposite vulcanizates claimed an increase of strain-induced crystallization without reduction of elongation at break and is mainly associated with the stronger rubber-clay interactions developed between MAH derivatives grafted NR and OMMT-S. The tensile strength, mod 300%, and elongation-at-break of Control-B vulcanizate are greater than those of Control-A vulcanizate by 150%, 24%, and 16% respectively (Fig. 2). With the addition of 2 phr loading of OMMT-S, B-2 nanocomposite vulcanizate exhibits better mechanical properties; B-5 nanocomposite vulcanizate shows remarkably increased tensile strength (41 MPa), mod 300% (6 MPa), and elongation at break (630%). The slippery action of plasticizers arranged as assemble structures would make it possible for the highly strained molecular chains to relieve the tension caused by stretching; hence, they will not break permanently, resulting in a higher strain at break and strength (Wu et al., 2004).
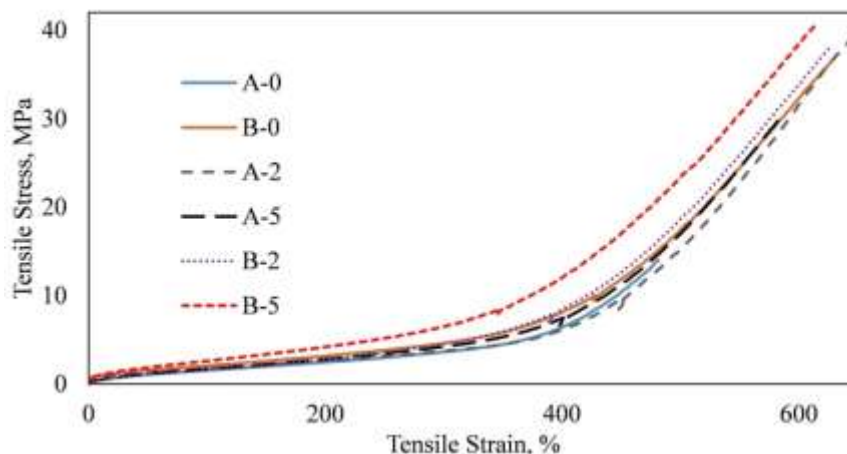
Fig. 1. Stress strain curves of the NR nanoclay composite vulcanizates
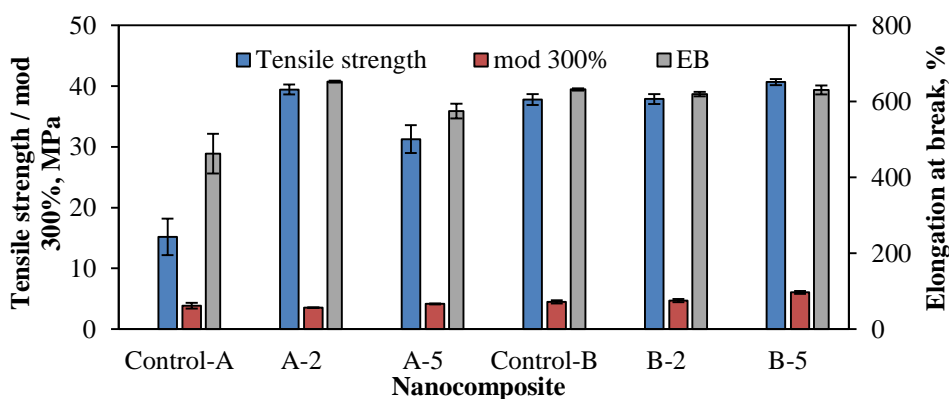
Fig. 2. Tensile properties of the NR nanoclaycomposite /control vulcanizates

4. CONCLUSION

This enhancement in strength is attributed to the improved interactions between maleic anhydride derivative grafted NR and clay, particularly evident at 5 phr of OMMT-S. The remarkable mechanical properties were achieved due to formation of physical crosslinks in acid free co-coagulated environment. The plasticizing effect of surfactant addition is counteracted by the presence of NR-clay interactions.

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NANOSTRUCTURED AL₂O₃/GRAPHENE AS NANO-ADDITIVES IN COCONUT OIL AS A NANO/BIO-LUBRICANT TO ENHANCE ENGINE OIL PERFORMANCE

S. J. Hettiarachchi*

Institute of Technology University of Moratuwa, Sri Lanka

*suniljayanthah@gmail.com

ABSTRACT: The usage of internal combustion engines (ICEs) for both personal and industrial purposes is expected to persist beyond 2050. However, due to environmental concerns, there is a growing call to reduce global reliance on petrochemicals and lubricants derived from fossil fuels. To address this, new strategies are needed to enhance ICE performance by minimizing friction, wear, fuel consumption, and exhaust emissions. This approach would mitigate the depletion of mineral and fossil fuel reserves and minimise environmental pollution. This study focuses on enhancing ICE performance using nano-bio lubricants. These lubricants are formulated using 2D nanocomposites of Al_2O_3/graphene as new additives in coconut oil, with performance comparable to mineral-based engine oil 15W40. The Al_2O_3/graphene nanocomposite synthesized via thermal annealing was found to have a rich sp^2 domain with spherical/laminar morphology and an ultra-fine particle size (<10 nm). When formulated as a nanofluid, it indicated consistent colloidal stability. Valuable insights into the tribological mechanism were acquired through several characterization techniques, containing friction and wear analysis. Reductions in the coefficient of friction (by 28%), specific fuel consumption (by 8%), and the emissions of exhaust pollutants (CO, SO_2, and NOx) were the significant achievements of optimizing a 2D tribological system using coconut oil formulation. This study showcases the advantages of utilizing nano-bio lubricants, which are developed with coconut oil and 2D-based hybrids as base stock and additives. These solutions can be applied to other areas where lubricants are essential such as improving fuel consumption while reducing environmental pollution to address global challenges.

Keywords: bio-lubricants, friction, nano-additives**,** wear

1. INTRODUCTION

In a contemporary, dynamic industry and environmentally conscious society, it is an escalating necessity to mitigate the environmental pollution caused by internal combustion engines (ICEs). This research focuses on saving energy and reducing the usage of fossil fuel and mineral reserves via enhanced lubrication, which reduces friction and wear in ICEs.

In this circumstance, bio-lubricants and nano-additives can play a pivotal role. Examples of nanomaterials added to lubricants include metal oxides of Al_2O_3, TiO_2, $TiSiO_4$ and recently reported 2D graphene derivatives. For example, (Gulzar et al., 2017) used 0.75 wt.% of $TiSiO_4$ (~ 50.0 nm) as a nano-additive in palm-trimethylolpropane (PTMP) ester and observed a 68% reduction in the coefficient of friction (COF) and a 50% reduction in the wear volume. (Philip et al. 2019) observed the enhancement of tribological performance by adding 0.50 wt.% of nano CuO (~ 50.0 nm) to coconut oil (CCO). (Abere J, 2017) utilized nanoparticles of Al_2O_3 (20.0 nm), SiO_2 (5.0 – 15.0 nm) and graphite (35.0 – 80.0 nm), 0.10 wt.% with untreated rapeseed oil and multigrade formulated mineral oil 15W40 and observed the enhanced tribological performance with combined additives; nanoparticles with zinc-dialkyldithiophosphate (ZDDP). (Philip et al., 2019) Acknowledge the optimized COF and wear reduction performance by the combination of CCO and hybrid Ce-Zr nanoparticles, 0.62 wt.%, with improved thermo-physical properties. (Ali et al., 2016) emphasized the enhanced tribological performance of Al_2O_3 nanoparticles (8.0 – 12.0 nm), 0.25 wt.% as an additive in formulated mineral oil 5W30 and revealed reductions of COF (35%) and wear rate (21%). (Meng, Su, & Chen, 2017) who studied the tribological properties of graphene, used mineral oil 10W40 as base-stock to blend with supercritical (Sc)-Ag/graphene nanocomposite (Sc-Ag/GN: spherical, 4.0–10.0 nm) as nano-additives and observed the reduction of COF (30.4%) and WSD (27.4%) with 0.06% ~ 0.10 wt.% concentration.

Bio-lubricants have been demonstrated to exhibit superior biodegradability, low toxicity, and higher viscosity index, compared to mineral-based lubricants. They are also more recyclable and renewable

and are thus good candidates to substitute for mineral-based lubricants (Syahir et al., 2017). Nonetheless, one set of limitations observed for bio-lubricants are their low-temperature characteristics; wax formation, poor cold flow, high pour point (PP), and low oxidative stability, all of which are qualities in need of enhancement (Syahir et al., 2017). There are numerous bio-lubricants containing plant oils or animal fats in use with reasonably similar molecular structures, commonly known as triglyceride molecules (Syahir et al., 2017). CCO has been selected in this research as the bio-base stock, because of the excellent availability.

The ICE is a heat engine, which converts chemical energy into kinetic energy via a combustion process with an approximate thermal efficiency of around 20 – 30% for gasoline and diesel engines (Tung & McMillan, 2004). Energy losses through heat transfer, sound generation and friction contribute to the low thermal efficiency (Tung & McMillan, 2004). (Ali et al., 2016) Estimated that 17-19% of the power generated by an engine will be lost through friction, of which perhaps the relative motion of the piston ring assembly and cylinder liner interface will account for 40-50% of frictional power losses within an ICE: this was later confirmed by (Jia et al., 2018).

This paper investigates the tribological behaviour of nano/bio-lubricants on ICE components. Particular emphasis is placed on the piston ring cylinder liner interface, where the use of nanoparticles as engine oil additives with bio-based sample formulations will be compared with the performance of a conventional multigrade mineral-based lubricant (15W40). The ambition is to identify the optimal engine oil formulation which reduces friction and wear, thus improving fuel economy and reducing exhaust emissions. It therefore follows that optimizing the ICE performance saves energy and reduces the depletion of fossil fuels and mineral reserves for a stable and sustainable environment.

2. METHODOLOGY

Mineral-based multigrade engine oil 15W40 as the reference oil and coconut oil (CCO) as the bio-based lubricant were selected respectively. Al_2O_3/graphene (G) nanocomposite was synthesized via thermal annealing (Jastrzębska et al., 2017) using nanoparticles Al_2O_3 and G as nano-additives to formulate sample blends. Synthesized nanocomposites were characterized using Transmission Electron Microscopy (TEM), X-ray powder diffraction (XRD), Raman, and X-ray Photoelectron Spectroscopy (XPS).

In this investigation, five sample formulations, including 15W40 as reference oil, were utilized. CCO was utilized as the base stock after enhancing its physicochemical properties (Hettiarachchi et al., 2023). Three weight concentrations of Al_2O_3/G were used with Oleic acid as the surfactant. All the samples were blended using an ultrasonic mixture and further agitated using a magnetic stirrer hot plate. A UV-Vis spectrophotometer was used to analyze the dispersion stability of formulated sample blends.

Segments of a piston ring and a cylinder liner of an ICE were used with a Linear Reciprocating Tribometer (LRT) to investigate the tribological characteristics of sample blends. A twenty-five (25) test conditions; combinations of 5 loads (120, 140, 160, 180 & 120 N) with 5 velocities (15, 20, 30, 40 & 50 Hz) at an elevated temperature of 140 °C were applied to simulate real ICE performance following guidelines of ASTM G181-11.

Scanning Electron Microscopy (SEM), Energy Dispersive X-ray Spectroscopy (EDX) and 3D noncontact optical profilometry techniques were utilized to analyze wear scars of test specimens following the LRT tests. A rheometer and a thermogravimetric analyzer were utilized to study the rheometric behaviour and thermal and oxidative stability of the formulated coconut oil (FCO). A dynamometer test rig with 4.8 kW capacity and an exhaust gas analyzer were used to investigate the

specific fuel consumption and exhaust emissions of formulated sample blends and compared them with the reference oil 15W40.

3. RESULTS AND DISCUSSION

The results of the TEM analysis revealed the average particle size for nanoparticles Al_2O_3/G as 10.0 ±0.3 nm with lattice fringe spacing for G in Al_2O_3/G as 0.37±0.01 nm, (Hayes et al., 2015; Seehra et al., 2015) with spherical/ laminar morphology, which are very vital properties to infiltrate through ultrafine asperities of piston ring cylinder liner interface (Meng, Su, & Chen, 2016; Song, Yan, & Ji, 2019) in comparison to the reported ICE lubrication film thickness (Garcia-Atance Fatjo et al., 2016). The XRD, Raman and XPS analyses confirmed the synthesized nanocomposite as Al_2O_3/G (Baragau et al., 2020; Kellici et al., 2014; Meng et al., 2016; Pakharukova et al., 2017).

From the LRT test results it is observed that the FCO can reduce the coefficient of friction (COF) by 7% for all test conditions (mean) compared with the reference oil (15W40) with a maximum COF reduction of 53% under the 180 N load with 50 Hz sliding velocity (frequency) without any additives. The sample lubricant containing Al_2O_3/G 0.1 wt.% as nano additives in FCO (FCO+Al_2O_3/G 0.1 wt.%) dominated throughout all 25 test combinations resulting in the reduction of the overall coefficient of friction (COF) by 28% with a maximum of 59% COF reduction for the 200 N/50 Hz load/frequency combination. From the UV-Vis analysis, it is observed that the sample FCO+Al_2O_3/G 0.1 wt.% has different degrees of sedimentation during the 0–72 h period with consistent colloidal stability thereafter throughout the experiment period (Gulzar, 2017; Hou et al., 2021). The thermogravimetric analysis confirmed the improved thermal and oxidative stability of FCO than CCO under the airflow. The presence of the chemicals added to improve the physicochemical properties of CCO could have contributed to this effect (Hettiarachchi et al., 2023). From the rheometric analysis, the FCO demonstrated improved shear stability compared to the reference oil under increasing temperatures (60, 80, 100, & 120 °C).

From the dynamometer test results it is examined that the reduction of specific fuel consumption by 8% by the sample FCO+Al_2O_3/G 0.1 wt.%. In addition, the reduction of CO, SO_2 and NO_x emissions was revealed from exhaust gas analysis. The ultra-fine alumina particle size (10.0 ± 0.3 nm), spherical/laminar morphology and low crystallinity when hybridized with 2D graphene have been attributed to dispersion stability and tribological enhancement. The formation of a protective tribo-film on the sliding interface was revealed through EDX analysis, showing the deposition of C, Ni, Cr, O, Mo, and K with traces of Al on wear surfaces, which completely covers the underlying Fe material.

4. CONCLUSION

The outcomes of linear reciprocating tribometer (LRT) tests, scanning electron microscopy (SEM) micrographs, energy dispersive X-ray spectroscopy (EDX) surface analysis, 3D optical analysis, exhaust emissions and specific fuel consumption analyses have proven the significant benefits of the tribological properties of coconut oil and Al_2O_3/Graphene nano-lubricant (FCO+Al_2O_3/G 0.1 wt.%).

The formation of a protective layer on the wear surface supported by secondary mending and polishing effects is further elucidated by SEM micrographs confirming the above phenomenon. During elastohydrodynamic lubrication (EHL), reduction of COF above 50% specifically at higher reciprocating velocities could be assigned to the laminar/spherical morphology of Al_2O_3/G nano-additives, which could be attributed to rolling or ball-bearing effect in place of sliding lubrication. Improved heat transfer attributes of coconut oil with Al_2O_3/Graphene nano/bio-lubricant were confirmed with the reduction of NO_x emissions emphasizing the comparatively low combustion temperature compared to reference oil (15W40).

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MACHINE LEARNING APPROACHES IN IN-SILICO DRUG DESIGN AND DEVELOPMENT: A COMPREHENSIVE REVIEW

S. M. Mahagama[1] and N. T. Jayatilake[2*]
[1]Institute of Technology University of Moratuwa, Sri Lanka
[2]Horizon Campus, Sri Lanka
sitharam@itum.mrt.ac.lk[1], nadunij@horizoncampus.edu.lk[2*]

ABSTRACT: Machine Learning (ML) is premised on the idea that machines can learn from data, recognize patterns, and make optimum decisions. Machine learning approaches include various algorithms for interpreting and gaining knowledge from data. Recently such ML-based techniques have been applied in drug development, bioinformatics, cheminformatics, and other areas of medicine as well. Drug design involves creating small molecules that are favorable in shape and charge to the biomolecular target to which they bind. Since experimental and lab procedures are limited in throughput, accuracy, and cost, they are unsuitable for broad deployment. Therefore, the development of in-silico target-drug designing methods has gained increasing attention globally due to the advantages of speed and low cost. In silico techniques in pharmaceutical designing are a type of computerized simulation that employs computer-aided technologies which initialize with an understanding of precise biochemical reactions within the body forming combinations of them to meet a therapy profile. Computerized methods provide the benefit of producing novel candidates for drugs faster and at lower prices. Virtual screening and de novo design, in silico ADME/T prediction, and improved methods for assessing protein-ligand interaction and structured-based drug design are the major functions of computational drug development. In-silico drug design refers to the use of computational methods and simulations to design and optimize drug candidates. This process involves steps such as Target Identification and Validation, Structure-Based Drug Design, Ligand-Based Drug Design, Virtual Screening, Molecular Dynamics Simulations, ADMET Prediction and Optimization. The adoption of ML algorithms in the search of medicines is applicable throughout this entire process. In this review article, the machine learning applications employed in In-silico drug design and discovery are explored in detail.

Keywords: computer-assisted drug design, drug discovery, in-silico drug design, machine learning

1. INTRODUCTION

Machine Learning (ML) approaches adopt various algorithms to teach machines to analyze data, recognize patterns, and make optimum decisions (Talevi et al., 2020). The limitations in throughput, lesser accuracy, and high cost in experimental procedures and lab equipment for traditional drug design have encouraged clinicians to increasingly adopt the Computer Assisted Drug Design (CADD) method, hence increasing global attention on in-silico target-drug designing methods, due to the advantages of speed and low cost. The in-silico drug design process involves steps such as Target Identification and Validation, Structure-Based Drug Design, Ligand-Based Drug Design, Virtual Screening, Molecular Dynamics Simulations, ADMET Prediction and Optimization (Rao, 2011).

This study addresses critical limitations in traditional drug design methods which are widely documented as being resource-intensive, costly, environmentally harmful, and ethically challenging due to high rates of chemical waste and reliance on animal testing (Rao, 2011; Dahl et al., 2014). With ML-based in-silico methods, recent research points to significant potential for faster, more sustainable, and economically feasible drug development processes, especially for underfunded areas like rare and neglected diseases (Rifaioglu et al., 2019; Patel et al., 2020). Despite these advancements, there is limited comparative analysis on efficiency, environmental benefits, and overall efficacy of specific ML techniques across drug design stages, a gap that this review aims to address. Therefore, the objective of the study is to analyze the benefits of machine learning methods in improving the drug design process focusing on how these methods enhance efficiency, sustainability, and precision of the drug discovery process.

2. METHODOLOGY

The methodology emphasizes the selection, classification, and assessment of studies from credible academic sources that demonstrate application of ML methods across seven critical phases of drug discovery to make the process efficient and effective (Shaker et al., 2021).The analysis aims to evaluate comparative effectiveness, benefits, and drawbacks of various ML approaches, including Deep Learning (DL), Random Forest (RF), Naïve Bayes (NB), and Support Vector Machines (SVM), as they pertain to various phases of in-silico drug development. The initial literature search was conducted using several academic databases including PubMed, Google Scholar, and Scopus which are well-regarded for their comprehensive coverage of biomedical research.

Key terms such as "machine learning," "in-silico drug design," and "computational drug development" were used as a guide to ensure relevance of the research material. The focus was put on peer-reviewed articles conducted during past 10 years to ensure the timeliness of the findings. Research showing empirical findings, which includes assessments of predictive accuracy, computational effectiveness, and practical uses of machine learning methods throughout the stages of drug development (such as target identification, lead optimization, and ADMET prediction, among others) and research articles that examine the use of machine learning in key stages of drug development, such as virtual screening molecular docking, and structure-based drug design were the inclusion criteria for the study. Articles that do not contain experimental or empirical evidence, including those that are entirely theoretical without real-world confirmation, research that only examines traditional (non-computational) approaches to drug discovery or machine learning applications in unrelated domains, and investigations that present incomplete or unclear explanations regarding the machine learning utilized were excluded.

The initial search provided approximately 35 papers. Then the titles and abstracts of identified articles were reviewed to assess their significance. Full texts of potentially relevant studies were then examined to determine their suitability and adoptable content. Nearly 23 works were sorted out in full text for reference. The reference management software 'Zotero' was used to store organize and keep track of the referenced articles, and to make the documentation efficient. The evaluation of Machine Learning Algorithms process included comparing the effectiveness of machine learning methods across different parameters and phases of drug discovery based on key performance metrics such as prediction accuracy, precision, recall, computational efficiency, advantages and limitations.

3. RESULTS AND DISCUSSION

Table 1 summarizes how these methods address inefficiencies, environmental problems, and economic issues integral to traditional drug discovery processes. Deep Learning (DL) techniques, particularly Deep Neural Networks (DNNs) have demonstrated success in activity prediction and drug repurposing. To illustrate this, Dahl et al. utilized DNN with 2D topological descriptors on the Merck Kaggle testing data surpassing the Random Forest (RF) method (Dahl et al., 2022). Moreover, Mayr et al. in their Tox21 project applied multitask DNN models to predict toxic effects using HTS data, and forecasting drug indications in the work of Subramanian et al. and Aliper et al. seem to imply DNN's useful applicability and accuracy in drug repurposing initiatives (Aliper et al., 2016). RF which is termed a supervised algorithm is also applicable in high volume datasets, for example in RF's applications; Cano et al. rank and reduce features to classify data with high rates whilst reducing computation (Cano et al., 2017). Regarding breast cancer, Naïve Bayes (NB) algorithm was effectively used by Pang et al. in discriminating active from inactive estrogen receptor antagonists and displayed potential to be desirable drug leads (Pang et al., 2018). Lastly, Support Vector Machine (SVM) algorithm proves especially useful for virtual screening and compound scoring tasks; thus, Patel et al. employed SVM to assess the molecular interactions which contributed

greatly towards compound selection and the search of therapeutic potential (Patel et al., 2020). These case studies demonstrate the advantages of each of the machine learning methods in furthering drug design processes.

Table 1. Applications, advantages and limitations of ML techniques in in-silico drug designing.

ML Model	Application	Prediction Accuracy	Computational Accuracy	Advantages	Limitations	References
Deep Learning (DL)	Activity Prediction, QSAR Modeling	~90% (QSAR model)	High resource consumption; efficient with large datasets	High accuracy for large datasets, flexible for various applications	Complex model validation; issues with generalization to new data (overfitting with small datasets)	Dahl et al., 2014; Rifaioglu et al., 2019
Random Forest (RF)	Lead Optimization, Predicting Drug-Target Interactions	~85%	Moderate (scalable for large datasets but longer training times)	Handles noisy data well, works with multiple data types, high prediction accuracy	Higher memory and time costs during training	Breiman, 2001; Cano et al., 2017
Naïve Bayes (NB)	Predicting Ligand-Target Interactions, Early Stage Drug Discovery	~70-80%	High computational efficiency (performs well with small datasets)	Performs well with smaller, noisy datasets, easy to implement, quick training times	Assumes feature independence; limited ability to capture complex patterns or correlations in biological data	Pang et al., 2018; Patel et al., 2020
Support Vector Machine (SVM)	QSAR Modeling, Virtual Screening, Predicting Molecular Properties	~80-85%	Moderate to high (can handle high-dimensional data, but memory-intensive with large datasets)	Effective in high-dimensional spaces, provides reliable predictions for drug-target interactions with limited data	Slow training times with large datasets, high memory consumption during screening	Patel et al., 2020; Dara et al., 2022

4. CONCLUSION

ML approaches allow for effective, precise and environmentally friendly drug discovery processes. This paper demonstrates that the techniques, including Deep Learning (DL), Random Forest (RF), Naïve Bayes (NB), and Support Vector Machines (SVM) have their comparative advantage in certain aspects of the drug design process. For example, it is well known that DL methods, while being resource costly systems prone to overfitting small datasets, can reach close to 90% accuracy in QSAR model predictions. RF models demonstrate strong results in lead optimization and manage to withstand the onslaught of noisy data, achieving 85% predictive accuracy but require enough memory and time to train. NB algorithms, due to their much lower computational requirements, allow for early-stage interaction between ligands and targets to be determined, although their ability to engage in complex biological systems is rather limited. Finally, SVMs perform well in virtual

screening and compound scoring, managing high-dimensional data effectively though they also consume large amounts of resources when the dataset is expansive.

Researchers have used ML algorithms and techniques to derive potential drug candidates and in improving the properties of drug molecules and compounds. Hence, clinical testing has become more efficient, time and money saving leading to sustainable engineering aspects while identifying new medicines. In consequence, the whole process has become faster, efficient and more accurate. Incorporating such advanced engineering solutions into the in-silico drug design and development process causes reduced wastage that takes place during various medical experiments which will decrease the carbon footprint aligned with the drug design process when compared with the conventional approaches. With this review it can be concluded that integrating Machine Learning into drug development not only boosts advancements and innovation but also drives the process more towards greener practices making things eco-friendlier to achieve global sustainability.

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EFFICIENT GLOVE EXTRACTION AUTOMATION SYSTEM

O.K.D.C. Nadeeshan[1], P.D.I.S. Polwaththa[2], L.R.S. Mendis[3], G.R.C.S. Dayawansa[4], G.H.D. Perera[5], and S.S. Morapitiya[6*]

[1,2,3,4,5,6]Institute**of Technology** University of Moratuwa**,** Sri Lanka

chamodnadeeshan2000@gmail.com[1], isahanjaya20@gmail.com[2], renuja.mendis@gmail.com[3], chan18kbv@gmail.com[4], hashinidilakmi@gmail.com[5], morapitiyas@itum.mrt.ac.lk[6*]

ABSTRACT: This paper focuses on the automated gloves removal system. In many industries, gloves are used frequently, but there is no proper system for their removal. In the medical sector, this becomes a critical issue that professionals face every day. There is a high risk of contaminating surfaces with germs during surgeries, and medical professionals must change gloves regularly. However, there is currently no automated system for glove removal; it is still done manually. The manual removal process is inefficient and time-consuming, and it also increases the risk of contamination. Therefore, this paper proposes an automated glove extraction system. While automatic glove-donning machines already exist on the market, there are no machines specifically designed for the automated removal of gloves. The proposed glove extraction system could not only be applied in the medical sector but also extended to industries such as pharmaceuticals, chemicals, and food processing, where safety and hygiene are paramount. The paper presents simulation results prior to the implementation of the prototype system. MATLAB programming and Wokwi.com, an online platform for simulating Arduino projects, were used to simulate and test the system's functionality.

Keywords: actuators and sensors, glove extraction and medical sector.

1. INTRODUCTION

The importance of frequent glove changes in the health sector is due to the high risk of spreading germs and infections to the patient and staff. However, there is an automated glove-donning system and there is no automated glove-removal system. Therefore, an automated glove extraction system can reduce the spread of germs, ensuring the process is both safe and efficient. With the automatic glove donning and removing system, the chemical industry and food industries enhance their efficiency without the need for manual hand sanitization. In these sectors, gloves are frequently removed for reasons such as healthcare protocols or food processing (Johnson & Rivera, 2022).

The industry implemented the automated glove-donning system that considers the requirements and efficiency of the medical sector as well as other sectors (Kapoor 2023; Tan 2024). It will take more time to remove gloves manually in emergencies and it is a significant challenge to healthcare professionals (Emerald Insight, n.d.). The most disadvantaged factor is germ infection among both patients and staff, it is high-risk in the medical sector (MACFOS, 2020; Robosavvy, n.d.). The main contribution of this paper is to introduce an automatic glove removal system and implement based on simulations. For future development, we suggested implementing the glove extraction system in the prototype and safe disposal. Due to infection, we focus on a proper automated system for disposal of gloves and sanitise the hands.

2. METHODOLOGY

The system was designed as mentioned in Fig. 1. The process begins with an ultrasonic sensor detecting the user's hand and sending a signal to open the door of the machine. The door is then opened using a rack and pinion linear actuator. Once the door is open, the user places their hand inside the machine, positioning it on a vacuum cup attached to an electric linear actuator, which is equipped with a slightly larger vacuum cup. Next, two additional linear actuators, each fitted with a slightly smaller vacuum cup, descend from above to grip the wrist area of the glove. The mouth of the glove is then widened as these actuators, along with a third actuator, move forward parallel to the hand, removing the glove. The removed glove is immediately directed into a bin. After this, the actuators return to their starting positions, ready to repeat the process for the next glove. Table 1 mentions the component list and technical details of the system design.

Table 1. Component list and technical details

Component List	Technical Details
Infrared (IR) Sensors	3.3V to 5V DC, 10-20 mA, 0.1W
Electric Linear Actuators	12V or 24V DC, ranges from 0.5A to 5A or more, depending on force and speed, 180W
Motors	12V DC, range from 0.5A to 2A, depending on the motor size and torque requirements, 5W
Actuators Operation	12V or 24V DC, from 0.5A to 5A, depending on the specific function and actuator size
Vacuum System	12V DC Mini Vacuum Pump, 12V DC, 1A to 5A, depending on the pump's capacity and usage
Solenoid valve	5W, 12V DC
Mini Vacuum Pump	48W
Arduino Mega 2560 Board	0.25W
Relay Module	4W
RF module kit	1W
LCD	0.5W
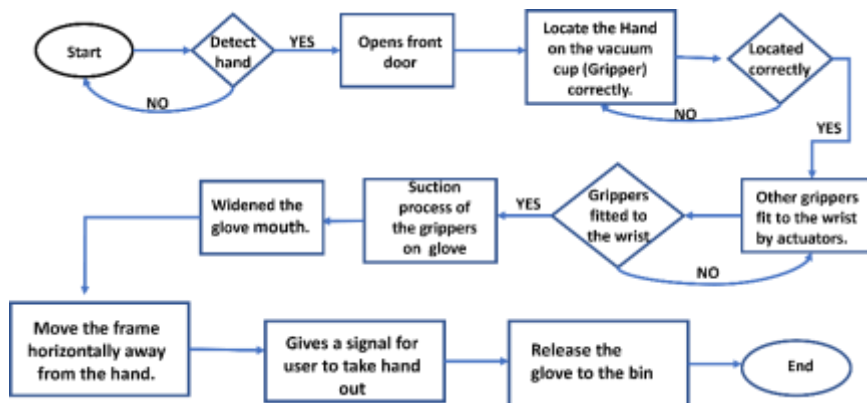
Fig. 1. The flowchart of the glove removal system.

To facilitate the initial testing and validation of our code, we utilized Wokwi.com, an online platform for simulating Arduino projects. Although the platform had limitations in terms of component availability, we employed similar components and made necessary assumptions to approximate the behaviour of our actual system. This approach enabled us to develop and test a preliminary version of our control code. The code was successfully compiled on Wokwi.com without errors, providing a robust foundation for further development.
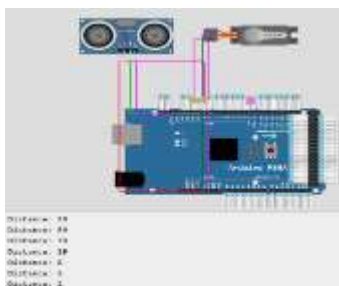
Fig. 2. When the distance is 2cm, the servo motor works.
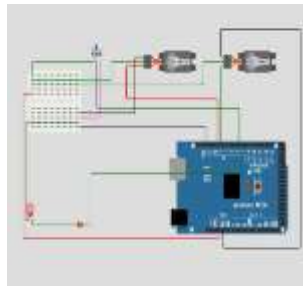
Fig. 3. Actuators moving forward.
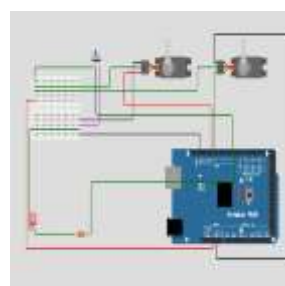
Fig. 4. Actuators moving backward.
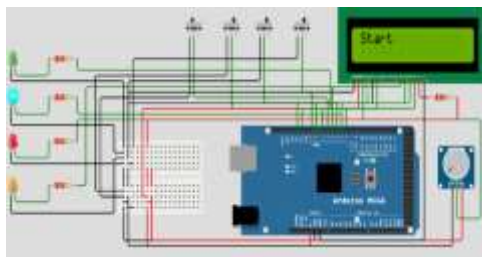
Fig. 5. The system display "Start".
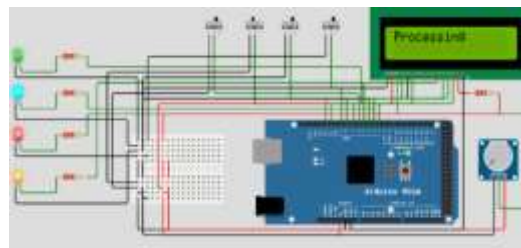
Fig. 6. The system display "Processing".
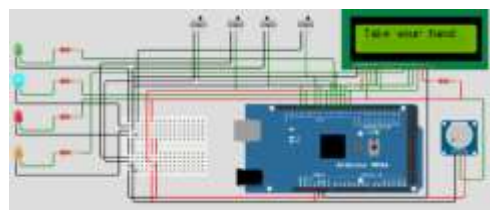
Fig. 7. The system display "Take your hand".
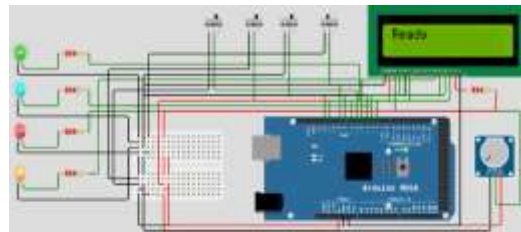
Fig. 8. The system display "Ready".

3. RESULTS AND DISCUSSION

In this section, we present the implemented circuit and the results of the glove-removing system.

Fig. 2 illustrates the results of opening the door when the hand is positioned two centimetres closer to the machine. Fig. 3 and 4 demonstrate that when the wrist of the hand is within two centimetres of the ultrasonic sensor, the sensor detects the hand and activates the servo motors in forward mode. The motors operate in this mode for three seconds, followed by a three-second pause to allow the vacuum pump to secure the wrist of the glove. Subsequently, the servo motors run in reverse for three seconds, causing the glove's mouth to widen. Fig. 5 shows the "Start" display, which appears when the door is opened. Fig. 6 depicts the "Processing" display, which is shown when the wrist is detected by the sensor on the actuator inside the machine. Fig. 7 illustrates the "Take Your Hand" display, which appears when the glove has been fully removed from the hand. Finally, Fig. 8 shows the "Ready" display, indicating that the system is prepared for the removal of the next glove.

4. CONCLUSIONS

In conclusion, our research aims to develop an automatic glove removal system and currently, it is not available on the market. It helps with the hygienic disposal of used gloves in operating theatres. The simulation model is developed and according to the simulation results, the system is working efficiently. In addition, the progress can be monitored using the display. This innovative system is designed to enhance efficiency and minimize the spread of germs, thereby contributing to a safer and more sterile surgical environment.

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ENHANCING VEHICLE CONNECTIVITY: LI-FI TECHNOLOGY FOR VEHICULAR COMMUNICATION

P.H.Y.C. Priyamantha[1], D.D. Karunarathne[2], M.G.B. Chamod[3], I.D.S. Sandeep[4], G.S. Diluksi[5], and S. S. Morapitiya[6*]

[1, 2, 3, 4, 5, 6,] Institute of Technology University of Moratuwa, Sri Lanka
yasiruchamika3400@gmail.com[1], deshandhananjaya13@gmail.com[2],
buddhimalchamod12@gmail.com[3], sachinsandeep74@gmail.com[4], gsdilukshi2000@gmail.com[5],
morapitiyas@itum.mrt.ac.lk[6*]

ABSTRACT: This paper aims to prevent accidents and ensure road safety by highlighting the importance of Vehicle-to-Vehicle (V2V) communication. V2V can ensure road safety, reduce vehicle collisions and enhance driver focus. we use Li-Fi technology for V2V communication, utilizing a Light Emitting Diode (LED) as the transmitter and a Light Dependent Resistor (LDR) as the receiver. The purpose of this project is to develop and implement a low-cost prototype system with advanced features designed to alert drivers in real-time. As a result, without any communication errors or delays, two vehicles can communicate within 3 meters. This enhances both vehicle and human security. Additionally, by integrating an alarm system, the project aims to help drivers focus more on avoiding accidents and improving road safety.

Keywords: Light Emitting Diode (LED), Li-fi and Light Dependent Resistor (LDR), Vehicle-to-Vehicle (V2V)

1. INTRODUCTION

The increasing number of vehicles globally presents several challenges, with road accidents rising daily due to traffic congestion. One solution to mitigate road accidents is the use of Li-Fi technology, which overcomes the limitations of microwave wireless communications. Li-Fi is a wireless communication technology that facilitates communication between two or more vehicles. In microwave communication working on MHz and GHz frequency ranges and Li-fi works on the THz frequency range. Li-fi technology uses light waves to transmit data. Li-fi is a subset of wireless optical communication. Light waves can communicate with Line of Sight (LoS) and communication speed is high and provides reliable communication. V2V communication is a popular concept and there are models with simulations. With Li-fi technology and sensor applications, it can achieve multiple services and able to avoid collisions between two vehicles.

Li-fi technology helps to transmit data more quickly than Wi-Fi. Li-fi is 100 times faster than Wi-fi. Li-Fi potential range is 10 Gbps and it is operating in THz frequency range. Also, it is a short-range communication method, and it can transfer data within milliseconds in V2V communication. In addition, LED and LDR are low-cost components, and these are the main components for the transmitter and the receiver in Li-Fi technology. With consideration of the Field of View (FoV) of LED and the LDR, they can communicate using the LoS. It is a huge benefit for such kinds of V2V applications. Limitations of the V2V communication using Li-fi are required LoS, response to the ambient light and limited coverage area due to the short-range communication system. Last few years, there have been a lot of road accidents on Sothern Expressway in Sri Lanka and the number of accidents has increased day by day as per (Daily Mirror, 2023 August 18). We identified the importance of a reliable communication system to communicate with adjacent vehicles and the need to pay more attention to drivers as per (Iftikhar et al., 2022). According to the literature survey, we discovered that implementing the system with new technologies ensures road safety as per (Song et al., 2022). Increase the communication between two vehicles using Li-fi technology and use as headlight and other light sources to transmit the message as per (Shafiqurrahman et at., 2023). Using existing sources of the vehicles can transmit data and implement the advanced communication system as per (Das et al., 2023). The most important factors are efficiency and real-time updates for reliable communication as per (Nguyen et.al., 2023).

The main contributions of the paper are 1. Implement prototype hardware system. 2. Implement a real-time update display system and emergency buzzer system. As a future development, we identify to implement additional safe modes such as overtaking and turns. It can improve road safety and avoid accidents.

2. METHODOLOGY

Sstem design

The proposed system is designed so that when the first vehicle applies its brakes, the brake lights are activated. In our prototype system, we used a transmitter with LED and a Receiver as a panel of LDR sensors. To develop the entire prototype system, we used Arduino Uno boards, Motor drivers, TT gear motor wheels, LCD, LDR sensors, LED lights, Battery holders, Batteries, Buzzer Module. The total cost for the overall system is 9000/-. The LDR panel in the second vehicle detects the illuminated brake lights, signalling that the front vehicle is slowing down. This information is then communicated to the driver of the second vehicle through a visual display and an alarm, providing an immediate alert to take necessary action.
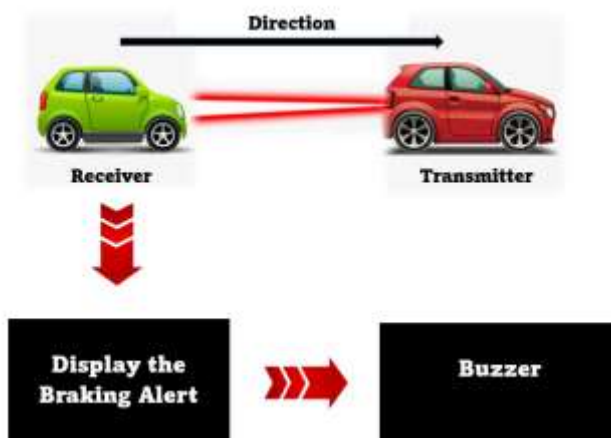
Fig. 1. The system block diagram of V2V communication.

Fig. 1 illustrates the block diagram of the V2V communication system designed for braking incidents of the front vehicle. Fig. 2 presents the schematic diagram of the transmitter with all technical details, while Fig. 3 depicts the schematic diagram of the receiver within the V2V communication system.
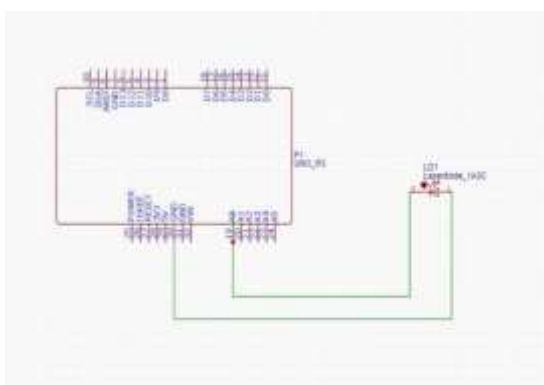
Fig. 2. Schematic diagram of transmitter.
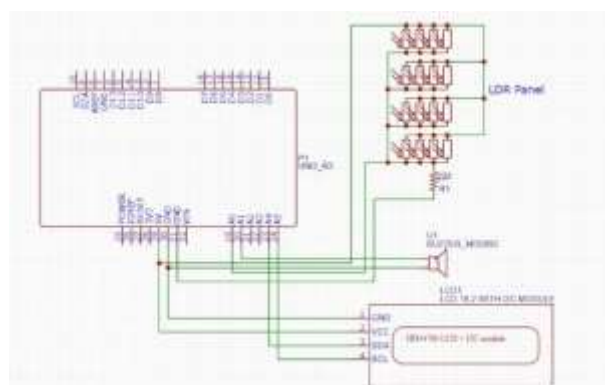
Fig. 3. Schematic diagram of receiver.

3. RESULTS AND DISCUSSION

In this section, we present the implemented circuit and results of the gas detection centralized system.
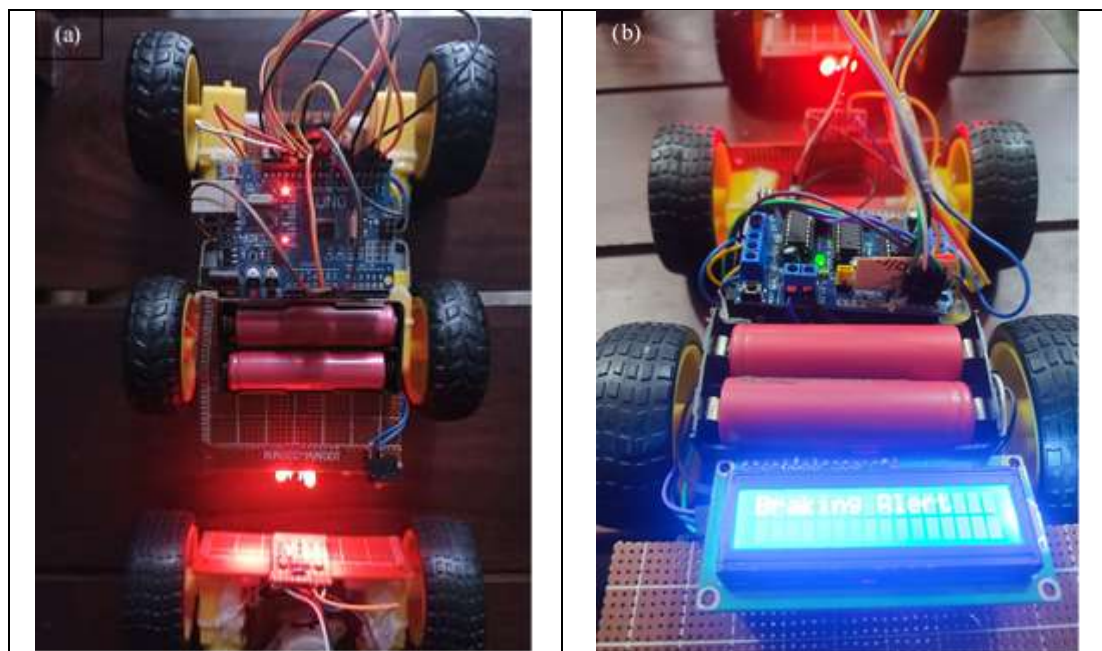
Fig. 4. (a) Implemented prototype design and communicate V2V (b) Display the braking alert and buzzer in the implemented design.

Fig. 4(a) shows the implemented prototype design, demonstrating the communication between two vehicles when one vehicle applies its brakes. Fig. 4(b) depicts the system in action, showing how the braking alert is displayed and accompanied by a buzzer sound to capture the driver's attention. In addition, tested within 3 meters of two vehicles. Without any error communicate the two vehicles and show in the display.

4. CONCLUSIONS

The proposed V2V communication system effectively enhances road safety by providing timely alerts to the driver of a following vehicle when the leading vehicle applies its brakes. By using a transmitter equipped with LEDs to simulate brake lights and a receiver comprising an array of LDR sensors, the system successfully detects the braking actions of the front vehicle. Upon detection, the system promptly communicates this critical information to the driver of the second vehicle through a visual display and an audible alarm. This immediate feedback allows the driver to react swiftly, reducing the chances of rear-end collisions and contributing to safer driving conditions.

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AN INTEGRATED METHOD TO ENSURING SAFETY IN GAS STORAGE FACILITIES

H.W.D. Dilshan[1], D.M.V.D.H. Dissanayaka[2], R.M.G.K. Dissanayaka[3], A.A.I.P. Eranga[4], R.S. Ranasinghe[5], and S. S. Morapitiya[6*]

[1, 2, 3, 4, 5, 6,] Institute of Technology University of Moratuwa, Sri Lanka

dilanthadilshan08@gmail.com[1], venuldissanayaka00@gmail.com[2], gkokila212@gmail.com[3], isurueranga.aip@gmail.com[4], reshinisheyadi@gmail.com[5], morapitiyas@itum.mrt.ac.lk[6*]

ABSTRACT: This paper focuses on the safety of the gas industry. We discuss the overall safety management system designed to reduce risks to both the work environment and workers. There are important features of this system such as real-time updates on gas leakage, a gas level indicator displaying the gas level and constant monitoring and communication with a centralized location. The method presented in this study is an integrated system with Internet of Things (IoT) developed with a web application and emergency management system. As a result, this system gives quick responses without exceed 200 milliseconds. Additionally, the system utilizes the AWS EC2 cloud hosting platform for communication and storage purposes.

Keywords: gas leakage system, microcontroller and IoT cloud platform, valve control system

1. INTRODUCTION

The most recent accident due to a gas leak occurred on the 23rd of August at a factory in Gujarat, India. Today, various types of gases are used in the industry, and large quantities are stored to meet national requirements. However, there is a pressing need to reduce risks in the gas industry through proper monitoring and a centralized system. The gas industry faces critical challenges such as explosions, improper storage of gas, leakage of gas and lack of advanced monitoring systems resulting in environmental pollution, economic loss, and life threats to both society and workers.

However, current gas leakage detection systems are not advanced, and depend on manual reporting. This results in a lack of alert systems, leading to high-risk operations (Senthil et al., 2023). IoT technology helps overcome these issues to a certain extend through real-time monitoring, warning alerts and automation of systems (Paul et al., 2021). There are some systems for monitoring Liquified Petroleum Gas (LPG) leakage integrated with IoT system. Other models emphasize LPG leakage detection and control systems that utilize Arduino, Global System for Mobile (GSM) modules, and Direct Current (DC) motors, incorporating Short Message Service (SMS)-based alert mechanisms (Jalel et al., 2023). One system proposes a Smart Natural Gas Leakage Detection and Control System (SNLDCS) specifically designed for gas distribution companies in Bangladesh. The SNLDCS is intended to detect gas leaks, monitor leakage information, and control gas supply to remote users (risers) through ON/OFF switching. This control is managed via an Android application over the internet (Li et al., 2020; Wang et al., 2021).

Another system utilizes an MQ-2 sensor to detect gas leaks and fire alarms, focusing on monitoring and management through an ESP32 processor. Additionally, a different IoT-based system has been proposed for detecting gas leaks, sending SMS alerts, and controlling the gas supply via an automated shutoff device (Zhang et al., 2020; Ren et al., 2015). The main contributions of the paper are:

  i. Design and develop a gas leakage system with a gas level indicator system.
  ii. Implement an IoT integrated system to control centrally.
  iii. Develop a user-friendly application for the web interface for monitoring and controlling systems.

As a future direction, this system can be designed with a Personal Protective Equipment (PPE) kit detection system to automatically recognize the safety clothing and equipment of workers, thereby helping to reduce the risk of accidents in a factory setting. This system is specifically designed for

industrial or large-scale natural gas distribution companies, allowing for remote monitoring and control of gas leaks from a central location.

2. METHODOLOGY

System design

The proposed system was designed to detect gas leaks in large gas terminals and control valves remotely using the IoT technology. It ensured quick response to potential hazards, preventing accidents and minimizing damage.

Fig. 1. Block diagram of Integrated Gas Leakage Detection System.

Fig. 1 shows the block diagram of the gas leakage detection system. This system comprises three subsystems such as gas leakage detection system, gas level indicator system, and communication system. All three subsystems can be centrally controlled. In a gas leakage detection system, gas sensors are strategically throughout the gas terminal, focusing on key areas that leak detection. Connect gas sensors to the ESP32 microcontroller and it has a dual- XSTensa® LX6 microprocessor it operates at 240MHz of clock speeds, which collects data from these sensors. The microcontroller processes the incoming sensor data and transmits it to a cloud platform. The cloud platform then analyses this data in real-time to detect any abnormal gas levels. If a gas leak is detected, the system generates an alert, which can be sent to designated personnel via email, SMS, or a custom notification system. Additionally, the proposed system includes a ventilation component alongside the gas leakage detection system. Operators can remotely access the valve control system through a user interface provided by the cloud platform. Upon receiving an alert, operators can activate actuators connected to valves to shut off the gas flow in the affected area.

Fig. 2 shows the Schematic diagram of the Smart gas leakage detection system which uses ESP32 to read both digital and analog data from the MQ2 sensor. MQ2 sensor measured in 200ppm-10,000ppm gas concentrations and response time is less than 10 miliseconds. Activate the Light Emitting Diode (LED) (green for safety, red for danger) trigger the buzzer if needed and use the Organic LED (OLED) display to show current gas levels, system status, and alerts. Fig. 3 shows the 3-D view of the gas leakage detection system.
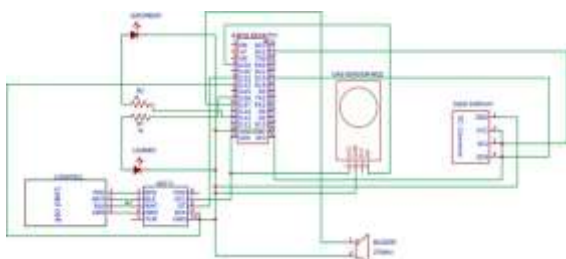
Fig. 2. Schematic diagram of Smart gas leakage detection system.
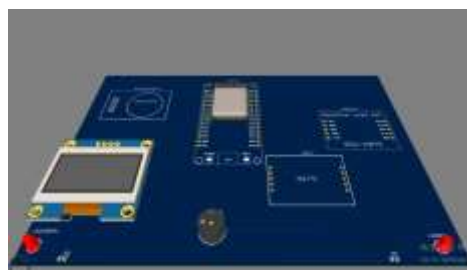
Fig. 3. 3-D view of gas leakage detection system.
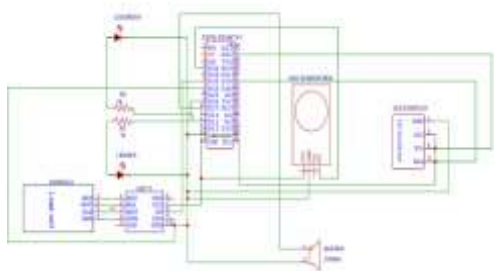
Fig. 4. Schematic diagram of gas level indicator system.
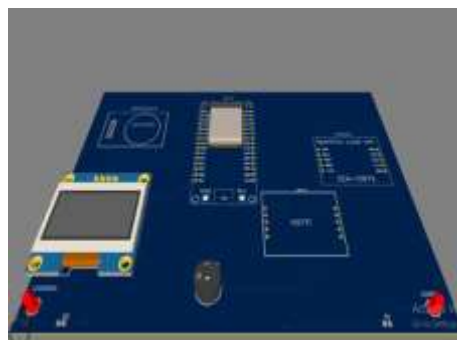
Fig. 5. 3-D view of gas level indicator system.

Fig. 4 shows the Schematic diagram of the gas level indicator system and uses a gas level detection system using a load cell, ESP32 microcontroller, HX711 amplifier, and a 16x2 Liquid Crystal Display (LCD) display. The system provides accurate and real-time monitoring of the gas level in a cylinder, ensuring timely refills and enhancing safety. Fig. 5 shows the 3-D view of the gas level indicator system. In the communication system, we use a cloud platform (AWS IoT Core/Azure IoT Hub) to connect the app and send the sensor reading to ESP32s.

3. RESULTS AND DISCUSSION

In this section, we present the implemented circuit and results of the gas detection centralized system. Fig. 6 shows the implemented circuit diagram of gas leakage and gas level indicator. Fig. 7 shows the gas leakage in the red button and the buzzer is activated. Fig. 8 shows the different gas levels in mobile applications. The importance of this system lies in its ability to centralize all data at a single point.

Fig. 6. Implemented circuit diagram of gas leakage detection and gas level indicator.

Fig. 7. Gas leakage detection results displayed in the mobile app

Fig. 8. Gas level detection display in the mobile app

4. CONCLUSION

This design integrates multiple gas leakage detection methods into an IoT solution. By utilizing microcontrollers, gas sensors, communication modules, cloud platforms, and mobile applications, this system is designed to detect gas leaks in real-time, generate alerts, and enable remote valve control. This integrated system gives quick responses without exceeding 200 milliseconds. These features collectively enhance safety measures and help prevent accidents, thereby improving overall safety and hazard management.

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EMPOWERING HERITAGE TOURISM THROUGH AUGMENTED REALITY: A REVIEW OF DIGITAL TRANSFORMATION FOR ECONOMIC SUSTAINABILITY

A.M.T.N. Adasuriya[1] and K. Galappaththi[2*]
[1, 2] Institute of Technology University of Moratuwa, Sri Lanka
tharukshin@itum.mrt.ac.lk[1], kgalappaththi@itum.mrt.ac.lk[2*]

ABSTRACT: Heritage tourism is a powerful driver of economic growth in Sri Lanka, largely due to its numerous UNESCO World Heritage sites and archaeological wonders. Hence, the cultural landscape of Sri Lanka offers a unique opportunity to showcase the nation's rich history to a global audience. Augmented reality (AR) emerges as a promising solution for boosting heritage tourism in Sri Lanka by providing an immersive experience for global visitors. While many developed countries have successfully implemented Augmented Reality to boost tourist engagement, its adoption in Sri Lanka remains in the early stages. Hence it is a very complex process to evaluate due to multiple characteristics such as technological, social, environmental, legal, and financial factors. To address these challenges, researchers conducted a systematic literature review using a qualitative approach and performed thematic analysis to identify key factors influencing AR adoption. As a result, the research highlighted the potential of using AR in the Sri Lankan heritage tourism sector by designing a new framework that provides key solutions such as digital infrastructure, cultural sensitivity, environmental conservation, legal guidelines, and fostering collaboration and government incentives. The framework supports the effective incorporation of AR in the Sri Lankan heritage tourism sector, providing a strategy for increasing tourist engagement and preserving cultural heritage. Hence, this will be a large step for Sri Lanka to be a leading destination in heritage tourism and to be built economically through sustainable tourism practices.

Keywords: augmented reality, economic sustainability, heritage tourism

1. INTRODUCTION

Heritage tourism is an important sector for economic development especially in nations rich in historical and cultural assets like Sri Lanka. With its diverse cultural landscape and numerous UNESCO World Heritage sites, Sri Lanka has the potential to emerge as a leader in this domain (Prabuddha et al., 2024). Augmented reality (AR) is a powerful technology that enhances experience by providing visitors with immersive experience. Numerous countries such as Italy, Greece, Romania, France, Spain, the United Kingdom, and China have successfully integrated AR into their heritage sites resulting in increased tourist engagement, a higher overall tourism revenue and improved educational outreach within the nation (Boboc et al., 2022). However, the main problem of the study is that the AR evaluation of heritage tourism in Sri Lanka is a complex process due to various factors. Wimalasuriya and Kapukotuwa (2020) recommended that future researchers evaluate key factors such as social, technological, environmental, financial, and legal aspects to explore more effective strategies for enhancing cultural heritage sites in Sri Lanka. Currently, AR implementation of the heritage tourism sector in Sri Lanka is in its early stages. As a nation with multiple traditions and numerous archaeological sites, it is essential to integrate digital technology into the Sri Lankan tourism framework (Galmangoda et al., 2022). This study aims to highlight the potential of AR in the heritage tourism sector by designing a new framework with some key solutions. The primary objective of this study is to review existing literature to evaluate the status of AR adoption in heritage tourism focusing on both international and local contexts for a sustainable economy. Further, the study aims to address the importance of leveraging AR not only for enriching tourist experiences but also for ensuring the economic sustainability of Sri Lankan heritage tourism.

2. METHODOLOGY

In this study, a qualitative approach was adopted, and existing literature was reviewed to investigate the prospects of AR in enhancing heritage tourism in Sri Lanka. A systematic and scientific analysis was conducted, focusing on literature that relates to AR in tourism

and successful implementations from other countries. Under clear inclusion criteria that cut across the focus areas of the study, including key words such as "augmented reality" and "sustainable economy" and "heritage tourism", a total of 40 sources were selected from databases like google scholar, Scopus, science direct and IEEE explore. The process of literature review and analysis is illustrated in Fig.1, which outlines the thematic approach, coding, sub-theme emergence, clustering, and framework development steps.
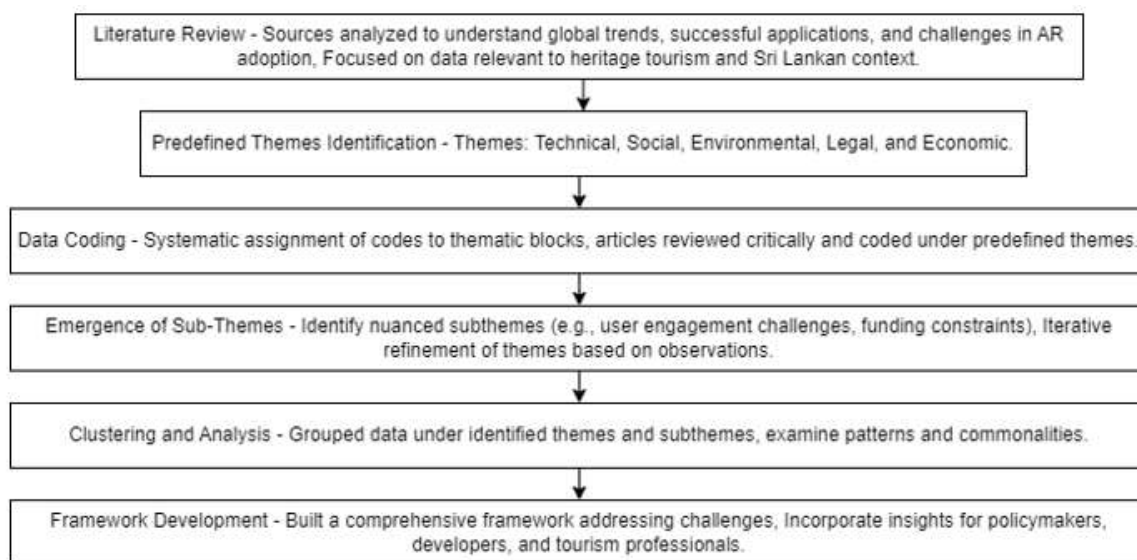
Fig. 1. Research Methodology

3. RESULTS AND DISCUSSION

3.1 The Role of AR in Heritage Tourism

AR is a technology that offers an immersive experience for the tourism industry, and it builds a bridge between the past and the present. It allows visitors to engage with historical stories in dynamic ways (Han et al., 2018). By integrating digital information with the physical environment, augmented reality allows the storytelling aspect of different heritage sites (Schaper et al., 2017). Further, it enhances making history accessible enhancing for a wider audience (Han et al., 2018). These technologies can transform static exhibits into dynamic experiences for users to engage with historical and cultural practices in a personal and immediate way (Hoang and Cox, 2017). Wimalasuriya and Kapuwakptuwa (2020) assert that augmented reality is a transformative tool in the context of the rich cultural heritage in Sri Lanka (Wimalasuriya and Kapukotuwa, 2020). Offering interactive storytelling sessions and virtual tours of heritage sites can enhance the educational aspects of tourism while saving the authenticity of cultural aspects (Bhaskara and Sugiarti, 2017). Further, it provides learning opportunities about Sri Lankan heritage with an enjoyable direction. By providing an immersive experience that blends education with entertainment, visitors can gain a deeper understanding as well as more enjoyable memories (Jung et al., 2014). This will be more helpful to get an idea about the significance behind each tradition and craft.

3.2 Adopting AR into Heritage Tourism

According to Wimalasuriya and Kapukotuwa (2020), integrating digital techniques into heritage sites is a very complex and long-term process in Sri Lanka. Technological, social, environmental, financial, and legal challenges need to be evaluated when planning the implementation, operation, and sustainability stages of the project life cycle. Hence, the study proposes a comprehensive

framework for the adoption of AR in Sri Lankan heritage tourism to overcome the challenges of a sustainable economy.
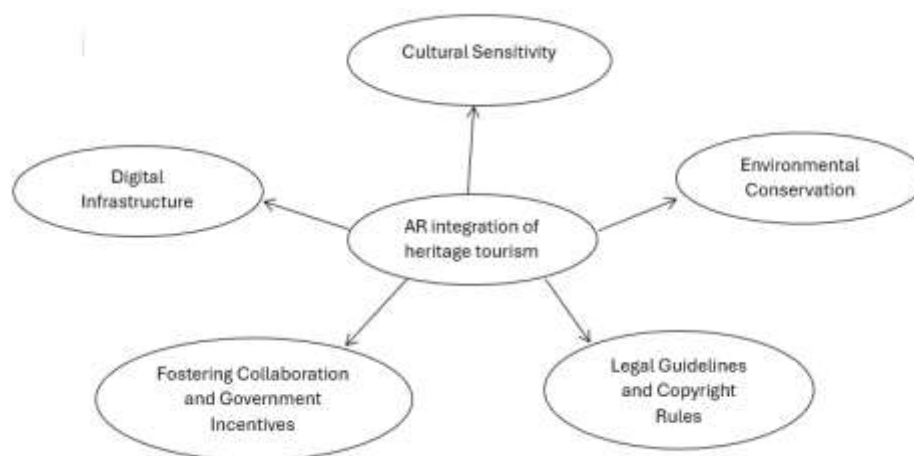
Fig. 2. Framework for AR integration of Sri Lankan heritage tourism

Technological infrastructure development is a foundational step in successful AR integration in the heritage tourism sector. Italy upgraded digital infrastructure on their major historical sites such as the Colosseum in Rome while ensuring high-speed internet access and stable mobile connectivity (Brunet et al., 2022). France has introduced user-friendly AR applications in popular heritage sites like "ABBEY OF EPAU" (Simonetto et al., 2013). Further, South Korea invested in technical training sessions for tourism professionals and site managers to ensure proficiency in maintaining and managing AR systems. Training programs help guide AR experiences and to troubleshoot the issues continuously (Koo et al., 2019). Technological infrastructure development in Sri Lanka should be prioritized due to lack of necessary digital infrastructure to enhance immersive AR experiences. The study suggests upgrading internet connectivity at heritage sites ensuring reliable high-speed network. Similarly, developing user-friendly smartphone applications would be an added advantage to enable visitors to access AR experiences without the need for special equipment.

The countries that successfully integrated augmented reality into cultural heritage tourism have prioritized social engagement and awareness to increase their cultural sensitivity (Cranmer, 2017). Nations like Spain and Italy have actively engaged with public awareness campaigns to promote the benefits of AR (Graziano and Privitera, 2020). Community involvement is a critical factor in AR projects to ensure cultural authenticity (Boboc et al., 2019). Local historians and cultural experts in Greece have collaborated on AR reconstructions at "Acropolis" (Karagianni, 2023; Stamati et al., 2022). Also, artisans and historians in India have been involved in developing AR contents that show the richness of local traditions (Vashisht and Sharma, 2024). These facts ensure AR technology preserves cultural heritage as well as resonates with local communities. France has invested in capacity building and training cultural and tourism professionals to implement and manage AR effectively (Danny Hana et al., 2018) Sri. Lanka needs to emphasize the significance of community involvement in creating AR applications that are both culturally and locally relevant. During the development process, historians, cultural experts and artisans should ensure AR experiences accurately reflect Sri Lankan tradition and historical narratives. Hence, the study proposes to launch public awareness campaigns to promote the benefits of heritage tourism not only for global visitors but also for the local community.

AR is a powerful technology to offer virtual access to sensitive and restricted areas because it reduces the physical impact of tourism. For example, "Manchu Picchu" in Peru, AR allows visitors to explore

areas virtually thus protecting the site from damage (Mann, 2018). Similarly, Iceland offers rich immersive experiences providing virtual tours while limiting foot traffic on sites (Guðjónsdóttir et al., 2022). Nations like Egypt have reduced the need for physical infrastructure through AR (elnoby osman et al., 2024). The Pyrami Giza provides an immersive experience for the visitors introducing natural environments (Orabi et al., 2022). In Sri Lanka, the study proposes AR as a tool while providing virtual access as a sustainable tourism practice reducing the physical footprint in sensitive areas. Also, highlights the significance of having AR to reduce the need for physical infrastructure to preserve the natural environment.

Countries that have successfully integrated augmented reality heritage tourism have recognized the need for a legal and ethical framework to protect both cultural heritage and technology (Yung and Khoo-Lattimore, 2017). Italy has developed legal guidelines to ensure AR reconstructions. Spain has established strict copyright laws to protect AR content related to cultural landmarks (Graziano and Privitera, 2020). Data privacy laws are also a crucial component. Most countries follow strict data protection standards, and they have implemented strong rules and regulations to ensure AR applications (Han et al., 2013). Sri Lanka needs intellectual property protection to safeguard the rights of content creators for projects involving historical elements or culturally sensitive. This may cause to protection of personal information to maintain AR platforms with high levels of trust and security.

According to the findings countries that have successfully integrated AR into heritage tourism have prioritized financial sustainability and investments through different aspects. Fostering private-public partnerships government bodies, technological companies, and cultural organizations collaborate to fund AR-related projects. In Italy, the collaboration between the private and public sectors has enabled the development of AR projects providing cutting-edge technology while preserving cultural heritage (Dubini et al., 2012). Government incentives also play a significant role in supporting AR adoption. A country like Singapore offers tax breaks for both tourism operators and technical developers who invest in AR technology for heritage sites (Ooi, 2006). The financial support encourages more stakeholders to be involved with AR-driven projects (Serravalle et al., 2019). Financial sustainability is the most important factor for Sri Lanka should be considered a developing country. Hence, the study advocates for private partnerships between government agencies, cultural institutions, and private tech companies to co-invest in AR projects. It is essential to provide financial incentives like tax breaks and grants to the Sri Lankan government to encourage tourism operators and AR developers to invest in this technology. The proposed framework identifies key aspects necessary for successful integration of augmented reality (AR) into heritage tourism in Sri Lanka. These include digital infrastructure, cultural sensitivity, environmental conservation, fostering collaboration and government incentives, and establishing legal guidelines and copyright rules. The visual representation of this framework is illustrated in Fig. 2.

4. CONCLUSION

Focusing on key features such as technical, social, environmental, legal, and financial is essential for the success of AR integration in Sri Lankan heritage tourism. The study highlights the potential of AR in the heritage tourism sector while designing a new framework with key solutions like digital infrastructure, cultural sensitivity, environmental conservation, legal guidelines and copyright laws, and collaboration and government incentives. Hence, the study concludes the research output in terms of findings as follows.

Improving network facilities, developing user-friendly smartphone applications, and effective management and maintenance are key solutions to overcome technical challenges. Launching public awareness campaigns to promote AR and creating culturally and locally relevant AR applications is

a successful strategy to overcome cultural sensitivity. Reducing physical infrastructure and physical footprint in sensitive areas is the best solution to overcome environmental conservation and the best possible solution to legal problems is to introduce intellectual property protection to safeguard the rights. Financial incentives, private and public partnerships, and the introduction of revenue models are the best outcomes that researchers have explored to overcome financial constraints.

The study faced few limitations since Sri Lanka remains in the early stages of AR adoption. Hence. the research is focused only on secondary data from articles related to international contexts due to the limited availability of local insights. The lack of AR projects in Sri Lankan heritage tourism is also another barrier to assessing the practical feasibility of AR adoption in the heritage sector. For future developments, the study suggests several directions for further research, including collecting primary data from local stakeholders, piloting AR projects at heritage sites, and assessing the direct impact of AR on visitor experience.

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A MOBILE APPLICATION FOR ENHANCED ATM SECURITY AND EFFICIENCY: COMBINING HELMET DETECTION, FRAUD PREVENTION, AND REAL-TIME CASH MANAGEMENT

D.S. Kuruppu[1*], K. Galappaththi [2], G.M.C. Prabhashwara[3], M.G. Nayanajith[4], W.L. Gimhan[5], and N.S. Madanayaka[6]

[2, 3,4,5,6] Institute of Technology University of Moratuwa, Sri Lanka
[1] Sri Lanka Institute of Information Technology, Sri Lanka
dushanthi.k@sliit.lk[1*], kgalappaththi@itum.mrt.ac.lk[2], 20it0491@itum.mrt.ac.lk[3], 20it0487@itum.mrt.ac.lk [4], 20it478@itum.mrt.ac.lk [5], 20it0465@itum.mrt.ac.lk [6]

ABSTRACT: Automated Teller Machines (ATMs) are essential for financial transactions but often lack robust security measures, especially in developing nations. In Sri Lanka, it is illegal to access ATMs while wearing helmets as it hinders identification in case of robbery or fraud. Additionally, customers are required to notify their banks if an ATM runs out of cash before the scheduled refill. To address these two issues a mobile application was developed by leveraging the Internet of Things (IoT) and Machine Learning (ML). A suite of technologies including Python, OpenCV, PyTorch, Firebase, and Flutter were incorporated to develop the application. The mobile application employs image processing and ML to detect individuals wearing helmets, triggering alerts for both customers and bank officials. OpenCV, a Python library for computer vision, is used for image processing and face detection to identify unauthorized wearers and alert bank officials in real-time. This feature enhances security by discouraging fraudulent activities and ensuring proper identification of users from fraudsters. The ML model trained for helmet detection reached a higher accuracy level of 99.94%. For efficient cash level monitoring, an IoT system integrates Infrared sensors with Arduino and is programmed with C++ to monitor ATM cash levels, providing proactive notifications to bank authorities before cash runs out, and minimizing service disruptions. The research contributes to improving ATM security and operational efficiency by combining advanced technologies with a user-centric design.

Keywords: ATM security, efficient ATM, IoT, Machine Learning, real-time cash monitoring

1. INTRODUCTION

ATM robberies are occurring all around the world. Fig. 1 shows the growth of ATM robberies from the year 2005 to 2020. However, the 2020 and 2021 statistical analysis shows a sharp increase in crime incidents at ATMs. ATM crimes in America increased by 600% from 2019 to 2020. These numbers were likely significantly influenced by the 2020 pandemic (Pinkerton. n.d.).
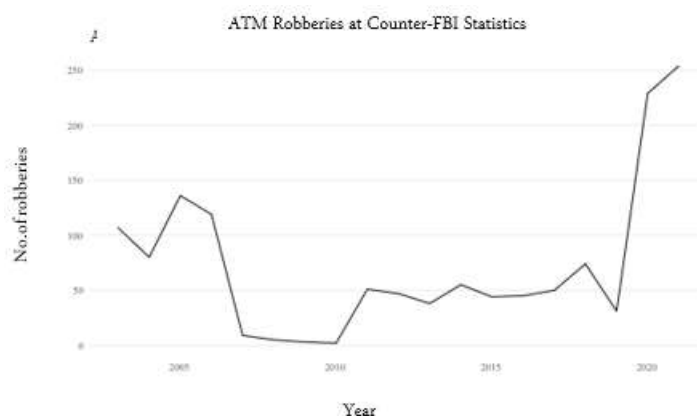
Fig. 1. Global ATM robberies

Although it is illegal to access Automated Teller Machines (ATMs) while wearing helmets in Sri Lanka, sometimes some users violate the rule as there is no specific person or procedure to monitor whether an ATM user is wearing a helmet or not. Even robbers and fraudsters can enter wearing helmets. Also, if an ATM is out of cash before the regular checkout from the bank, customers must inform the relevant bank, and then only bank officials visit the relevant ATM and refills. To address these two issues a mobile application was developed by leveraging a combination of sensors,

cameras, and Artificial intelligence (AI) algorithms to detect unauthorized wearers, monitor cash availability, and alert bank officials in real time. The system utilizes an IR sensor to track the thickness of the cash stack, and an ML model to identify unauthorized helmet wearers, by analysing the CCTV footage. Upon detecting unauthorized access, the system triggers an alarm, blocks transactions, and provides detailed information to bank officials via a mobile application. This proactive approach not only enhances security by deterring fraudulent activities but also improves operational efficiency by enabling timely replenishment of cash and minimizing downtime. By addressing these concerns, Mobile applications foster greater customer trust and ensure seamless ATM transactions.

Several approaches have been implemented to enhance security and efficiency in ATM functionality. This section similar studies are discussed on addressing vulnerabilities and improving ATM efficiency. Similar approaches are discussed under three sub-categories; "unauthorized access prevention", "transaction security and efficiency", and "accessibility and user experience".

Smart ATM security system using False Positive Rate (FPR), Global System for Mobile Communication (GSM), and Global Positioning System (GPS) proposes a multi-layered security approach. It has been integrating Radio Frequency Identification (RFID) cards, Infrared (IR) sensors, GSM, and GPS technology. The system aims to detect tampering, track ATM locations in case of theft, and verify authorized bank personnel (Saranraj et al.,2020). The safety helmet detection for ATM's surveillance system via the modified Hough transform utilizes DL techniques to identify individuals wearing helmets to hide their identity to prevent unauthorized access (Bharati et al.,2017). DL Helmets-Enhancing Security at ATMs investigates helmet detection using Convolutional Neural Network (CNN) suspicious behaviour within the ATM environment. (Jacintha et al.,2017)

An IoT-based ATM Surveillance System aims to identify theft attempts by sending alerts through social media platforms and dispensing chloroform to incapacitate potential intruders (Wen et al.,2003). ATM security system using Arduino proposes a solution which is a combination of fingerprint authentication and One-Time Password (OTP). (Jacintha et al, 2017). The design of the Embedded Based Dual Identification ATM Card Security System uses both fingerprint recognition and OTP generation. This replaces traditional ATM cards with secure biometric authentication, minimizing the risk. (Chumuang et al., 2020).

A money detector module has been developed based on Light Dependent Resistor (LDR) sensors to help blind people identify bank notes. This system uses voice output to communicate the detected value. (Devi at al.,2019)

2. METHODOLOGY

The proposed mobile application consists of two modules: "Unauthorized Wear Detection" module and the "Run-out-of-Money Detection" module. The "Unauthorized Wear Detection" module employs image processing technology to identify users wearing helmets before they initiate a transaction. If a helmet is detected, the ATM triggers a warning alert for both the customer and bank officials. The second module monitors cash levels within the ATM, notifying the bank when the cash before cash runs out, allowing for proactive replenishment.

Collaboration with bank officials was crucial for gathering requirements and detailed information about ATMs, transactions and the internal structure of the machines. The agile development methodology was followed during the mobile application development process. Figma was utilized for designing and prototyping the user interface, while the front-end user interfaces were built using the Flutter framework, providing a visually appealing and responsive experience across multiple devices. Google Colab was used as the development environment using libraries such as TensorFlow

and Keras to build and train the model. The "OpenCV" library was used for image pre-processing and face detection. An open data set was downloaded to create the training dataset.

In the first stage, data loading and pre-processing were conducted. It included image loading, resizing, and converting to arrays. Techniques such as rotation, zoom, shift, shear, and flip were applied to increase dataset diversity. For helmet detection, ResNet50 was used as the base model, with a custom head model added. The base layers were frozen, and only the head was trained. The model was trained using the Adam optimizer, with performance evaluated on a test set and visualized using Matplotlib. Face Detection was performed using OpenCV's cv2.dnn module with a pre-trained SSD model to detect faces in images. The trained model predicts helmet usage, and results are displayed with bounding boxes and labels on images.

The development environment utilized Visual Studio Code as the IDE and Firebase for cloud-based services and data storage. Version control was managed through Git and GitHub. Furthermore, Arduino was integrated for basic Internet of Things (IoT) device that is ATM cassette development within the project. IoT components, powered by "C++" programming with an Arduino Uno board, acquire real-time data from an IR sharp distance sensor to

Fig. 2. Structure of the cash-cassette of the ATM designed to monitor cash level

monitor cash levels, transmitting data to the Firebase database via an ESP8266 Wi-Fi module. Firebase's real-time database capabilities ensured timely communication between the system and bank officials regarding alerts and notifications. The combination of these technologies has created a comprehensive mobile application that enhances ATM security, operational efficiency, and user experience.

Equation 1 was used to calculate the cash level in the ATM cassette. When the remaining cash level (d) reaches 30%, a notification is sent to the bank official to remind them to refill. This notification level can be customized according to the requirements of bank officials.

$$d = \left(\frac{b}{a}\right) 100\% \; ; \; (b = a - c) \qquad \text{……………………………..} \qquad \text{Equation 1}$$

a=Total length of the cash cassette   b= Length of the note bundle

c=IR Sharp distance sensor reading length   d=% of the remaining currency note

Challenges encountered during implementation included high cost of physical components, the need for custom datasets for helmet detection, and the complex integration of diverse technologies. Despite these hurdles, the chosen technologies have facilitated the development of a robust system that enhances ATM security, operational efficiency, and user experience.

3. RESULTS

The training loss and accuracy of the ML model as the number of epochs increases are shown in Fig. 3. It is evident that the training loss decreases up to epoch 1.0 and remains constant while the validation loss (val_loss) remains constant without being affected by the number of epochs. Fig. 4 shows the output of the model identifying an image of a person wearing a helmet. The model achieved a high accuracy level of 99.94%.

`<matplotlib.legend.Legend at 0x7db6501fb2b0>`
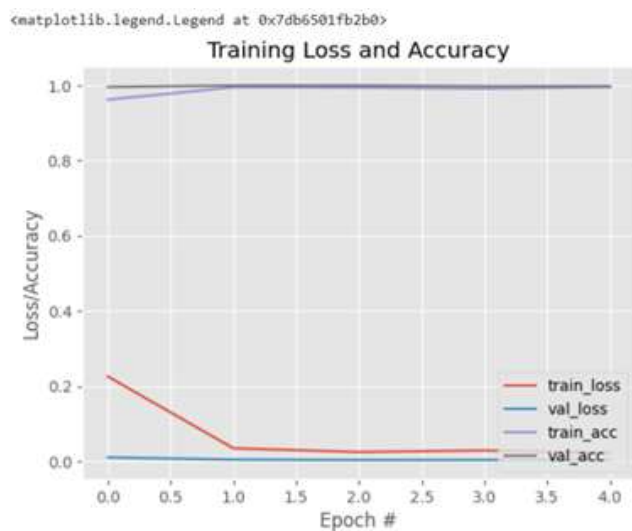
Fig. 3. Accuracy of the machine learning model for helmet detection

Fig. 4. Model identifies wearing helmet image with 99.94% rate of accuracy

4. CONCLUSIONS

The system developed in this study addresses security and efficiency concerns in ATM operations through a mobile application that leverages deep learning and image processing. The system detects unauthorized helmet and jacket wearers, triggering alerts for both customers and bank staff, while also providing real-time notifications about cash availability, ensuring proactive replenishment. Utilizing Python, OpenCV, PyTorch, Flutter, and Firebase, the solution aims to enhance security, improve operational efficiency, and promote customer satisfaction, ultimately fostering a seamless and secure ATM experience for all users.

To design an ATM system covering all problems in operation, this paper suggests implementing an alert system for bank officials when the receipt paper roll runs out and an ML model to detect ATM customers wearing jackets during the transaction.

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A REVIEW ON FRACTIONAL CALCULUS AND ITS APPLICATIONS IN ENGINEERING

C. I. Perera[*]
Institute of Technology University of Moratuwa, Sri Lanka
pereracassian@gmail.com[*]

ABSTRACT: The main purpose of this research is to explore the evolution of fractional calculus from its inception to its diverse applications in science and engineering. The concept of calculus dates back to the work of Sir Isaac Newton, an English mathematician, and Gottfried Leibniz, a French mathematician who presented similar ideas using different notations. Initially, the order of differentiation was understood as an integer. However, as time progressed, mathematicians encountered a paradox: what if the order of a derivative were not an integer but a fraction? This question marked the beginning of fractional calculus.

Over the years, a lot of definitions were developed by renowned mathematicians such as Euler, Lagrange, and Laplace. In its early stages, fractional calculus was primarily theoretical with little application to practical problems. However, as the field matured, mathematicians began to apply this theory to practical situations. Today, fractional calculus has seen rapid development and application across various domains in science and engineering. Some applications are shortlisted as follows. In the field of computer and electrical engineering fractional calculus is used in noise filtering processes, particularly in echocardiographic imaging, to minimize noise interference. It also plays a crucial role in developing de-noising models in digital imaging. In mineral engineering, leaching column test is conducted by using new rate equation formed by fractional calculus. The Behaviour of Hydrological processes on Earth has been mathematically modelled using fractional calculus. In the field of quantum mechanics, the Schrödinger equation has been further improved using the fractional calculus theory in the formation of a new version of the fractional Schrödinger equation in the context of space-time.

Keywords: Fractional calculus, fractional derivative, fractional integral.

1. INTRODUCTION

The subject of calculus, one of the most important branches of mathematics, has its roots in problem-solving practices dating back to the Babylonian era. However, it was formally developed in the 17th century by two great mathematicians: Sir Isaac Newton (1642–1727) and Gottfried Leibniz (1646–1716). At that time, calculus was primarily divided into two main components: differentiation and integration, both of which were confined to integer orders. A significant question arose regarding the implications of a derivative order that was not an integer but a fraction. This inquiry was raised by the mathematician L'Hôpital, referencing the work of Leibniz (De Oliveira et al., 2014). Leibnitz's reply was that it may be a paradox. However, it would be very helpful in the future (Debnath, 2004). This was the starting point of Fractional Calculus. It means that 'fractional calculus 'was born to deal with the order of derivatives in non-integer.

From that time until 1900, there was slow progress in the development of theories on 'fractional calculus'. (De Oliveira et al., 2014). However, after Leibnitz, there were great mathematicians who applied worthy efforts to formulate theories on fractional calculus. For example, Euler in 1738, Lagrange in 1772, Laplace in 1812, Lacroix in 1819, Fourier in 1822, Riemann in 1847, Green in 1859, Holmgren in 1865, Grunwald in 1867, Letnikov in 1868, Sonini in 1869, Laurent in 1884, Nekrassov in 1888, Krug in 1890, Weyl in 1919, Caputo in 1967, Khalil et.al in 2013 all contributed valuable efforts to the formulation of theories on fractional calculus (Lazarevic et al., 2014).

2. HISTORY OF FRACTIONAL CALCULUS

Let us examine the work done on fractional calculus by various mathematicians over the years.

2.1 From 1700 to 1750

2.1.1 Euler

In 1730, Euler derived a formula for $the\ n^{th}$ derivative of a power function as follows:

$$\frac{d^n x^m}{dx^n} = \text{m (m − 1) (m − 2)… (m – n +1)} x^{m-n} \text{------- (1) (Dalir et al., 2010)}$$

He later expressed it using Gamma functional notation:

$$\frac{d^n x^m}{dx^n} = \frac{\Gamma(m+1)}{\Gamma(m-n+1)} x^{m-n} \text{------- (2)}$$

where Gamma function is defined as : $\Gamma(n) = \int_0^\infty e^{-t} t^{n-1} dt = (n-1)! \; ; n \in R^+$

2.2 From 1801 to 1850

2.2.1 Lacroix

In 1819, Lacroix expressed the 'fractional derivative' of a power function assuming that it is similar to the nth derivative of the power function $y = x^m$ in 'classical calculus' where m is a positive integer, $m \geq n$ (Kimeu, 2009):

$$\frac{d^n y}{dx^n} = \frac{\Gamma(m+1)}{\Gamma(m-n+1)} x^{m-n} \text{------ (3)}$$

2.2.2 Loiuville

In 1832, Loiuville formulated the **n**th derivative of an exponential function as follows:

$$D^n e^{ax} = a^n e^{ax} \text{------ (4)}$$

When a function $f(x)$ is given as a series of exponential terms, the fractional derivative of order v of the function $f(x)$ was found by Loiuville as follows:

$$D^v f(x) = \sum_{n=0}^\infty c_n a_n^v e^{a_n x} \text{------- (5)} \quad \text{where } f(x) = \sum_{n=0}^\infty c_n e^{a_n x}$$

Debnath (2004) states this was his first definition on fractional derivative and his second definition was associated with Gamma functions.

$$D^\alpha x^{-\beta} = (-1)^\alpha \frac{\Gamma(\alpha+\beta)}{\Gamma(\beta)} x^{-\alpha-\beta} \text{------ (6)}$$

$$\text{(Debnath, 2004; Ross, 1977)}$$

Where $\beta > 0$. If $\beta = 0$, the function become unity. Then, fractional derivative of unity (x^0) would not be equal to zero even though the derivative of unity in traditional calculus is zero (Lazarevic, 2014; Debnath, 2004). However, according to De Oliveira (2014), his next definition on fractional derivative of any function of order α in terms of integral is:

$$D^\alpha x^{-\beta} = \frac{1}{\Gamma(1-\alpha)} \frac{d}{dx} \int_{-\infty}^x (x-\xi)^{-\alpha} f(\xi) d\xi \text{------- (7)}$$

Where $-\infty < x < \infty$.

Liouville was the first person to apply fractional derivative knowledge to solve differential equations in traditional calculus. (Ross, 1977)

2.2.3 Riemann

Riemann derived the following formula that shows how to find fractional integral of a function $f(x)$.

$$D_{c,x}^{-\alpha} f(x) = \frac{1}{\Gamma(\alpha)} \int_c^x (x-t)^{\alpha-1} f(t) dt + \Psi(x) \text{------ (8)}$$

where $D_{c,x}^{-\alpha}$ denotes the fractional integral of order α while c, x are limits of integration (Lazarevic, 2014; Ross, 1977).

Here $\Psi(x)$ is referred to as the complementary function which was a term introduced by him. Later, a new version of this fractional integral was published omitting the complementary function (Ross, 1977) as mentioned below(Debnath, 2004; Kimeu, 2009).

$$D_{c,x}^{-\alpha} f(x) = \frac{1}{\Gamma(\alpha)} \int_c^x (x-t)^{\alpha-1} f(t) dt \text{------ (9); } \alpha > 0$$

This is known as the "Riemann – Loiuville definition of fractional integral" which is attributed solely to Riemann when c = 0, otherwise belongs to Loiuville if $c = -\infty$ (Debnath, 2004).

2.2.4 Caputo

Caputo defined his own fractional derivative of a function as:

$$D_a^\alpha f(t) = \frac{1}{\Gamma(n-\alpha)} \int_a^t \frac{f^{(n)}x}{(t-x)^{\alpha-n+1}} dx \text{ ------- (10)}$$

where $\alpha \in$ [n-1, n), D_a^α is the fractional derivative operator, with **α** as the order and **a** as the lower limit of the integral included in the formula. (Khail et al., 2014)

2.3 The Time Period After 2000

2.3.1 Khalil et al.'s Definition for Fractional Derivative of Order α

Case 1: If $0 < \alpha \leq 1$

Definition:

Given a function **f: [0, ∞) → ℝ**. Then the fractional derivative of f order **α** is defined by

$$T\alpha f(t) = \lim_{\varepsilon \to 0} \frac{f(t+\varepsilon t^{1-\alpha})-f(t)}{\varepsilon} \text{ ------ (11)}$$

This definition is true when **α** = 1. Because when **α** = 1 it yields,

$$T\alpha f(t) = \lim_{\varepsilon \to 0} \frac{f(t+\varepsilon)-f(t)}{\varepsilon} \text{ ------- (12)}$$

This is the result of the first principle derivation of the first derivative of a function f in traditional calculus.

Case 2: If $n < \alpha \leq n+1$

Definition:
Let $\alpha \in$ (n, n+1], and f be an **n**-differentiable at t (>0). Then, the fractional derivative of order of **α** is defined as:

$$T\alpha f(t) = \lim_{\varepsilon \to 0} \frac{f^{(\lceil\alpha\rceil-1)}(t+\varepsilon t^{(\lceil\alpha-1\rceil)})-f^{(\lceil\alpha\rceil-1)}(t)}{\varepsilon} \text{ ------- (13)}$$

2.3.2 Fractional Integral

Definition:
According to Khalil, et al. (2014), α- fractional integral of a function f (t) is as follows:

$$I_\alpha^a f(t) = \int_a^t \frac{f(x)}{x^{1-\alpha}} dx \text{ ------ (14)}$$

If the α- fractional derivative of the above integrand is determined, it could be proved that the final result would be $f(t)$ confirming the accuracy of this method.

3. APPLICATIONS IN SCIENCE AND ENGINEERING

Some applications in science and engineering could be short listed as follows.

In the field of computer and electrical engineering, fractional calculus has been applied in noise filtering processes to reduce noise in echocardiographic imaging (Saadia et al., 2018). He et al. (2014) demonstrated how fractional-order differentiation is beneficial in developing de-noising models in digital imaging. In mineral engineering, leaching column tests are conducted using new rate equations formed by fractional calculus (Jaques et al., 2017). Research conducted by Zhang et al., (2017) shows the behavior of Hydrological processes on earth has been mathematically modelled using fractional calculus. Laskin (2017) illustrated the usefulness of fractional derivatives in formulating a new version of the fractional Schrödinger equation in the context of space-time within quantum mechanics. Recent applications of fractional calculus extend to dynamical systems including control theory, electrical circuits, viscoelasticity, electrochemistry, tracer in fluid flows, and model of neurons in biology.

4. CONCLUSION

This paper explores the definitions of fractional derivatives and fractional integrals of functions, highlighting the "Riemann–Liouville definition" and the "Caputo definition" as the most widely used. Initially, these concepts were not applied to practical situations. However, there has been rapid development in various scientific fields, including quantum mechanics, as well as in electrical, chemical, and civil engineering, through the application of fractional calculus. This approach addresses practical scenarios more effectively than classical calculus. Furthermore, applying fractional calculus to fractional partial differential equations (fPDEs) could significantly enhance research on the Earth's hydrosphere in the future.

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AI IN SRI LANKAN UNIVERSITIES :A SYSTEMATIC REVIEW OF ITS IMPACT ON EDUCATIONAL SUSTAINABILITY AND STUDENT EXPERIENCE

W.S. Kodippili[*]

Institute of Technology University of Moratuwa, Sri Lanka

waruni323@gmail.com[*]

ABSTRACT: This systematic review explores the transformative impact of artificial intelligence (AI) on university life and the sustainability of learning in Sri Lanka. AI technology is reshaping the landscape of higher education, influencing everything from personalized learning experiences to administrative efficiency and resource optimization. The primary objective of this review is to assess the existing body of research on AI applications in Sri Lankan universities, focusing on how AI-driven solutions can enhance educational sustainability and improve student experiences. Methodologically, a comprehensive search of academic databases was conducted, and ten studies were selected based on relevance to AI in Sri Lankan education. Key findings highlight that AI technologies are instrumental in adaptive learning, improving student engagement, and predicting academic success. This review concludes that AI offers significant benefits by enhancing learning quality, fostering inclusivity, and optimizing resources while also identifying infrastructural and policy challenges that must be addressed. Overall, AI presents a promising future for the development of a sustainable educational ecosystem in Sri Lanka.

Keywords: Artificial Intelligence (AI), educational sustainability, student engagement, university education

1. INTRODUCTION

In recent years, integration of AI in education has gained substantial momentum globally, with applications that offer the potential to enhance learning, streamline administrative tasks, and support sustainable educational practices. For students in Sri Lanka, these technologies provide an opportunity to access more personalized and efficient learning experiences, helping to address constraints posed by limited resources and a growing student population. This systematic review aims to understand how AI applications are currently being utilized in Sri Lankan universities and the ways in which they contribute to a sustainable and transformative educational experience for students. The primary objective of this systematic review is to evaluate the transformative impact of AI on the sustainability of university education for students in Sri Lanka. Specific objectives include examining the role of AI in personalized learning and student engagement, identifying how AI aids in resource optimization and administrative efficiency, and assessing challenges faced in implementing AI technologies within Sri Lankan universities.

2. METHODOLOGY

To ensure a comprehensive review, academic databases including Google Scholar, IEEE Xplore, and PubMed were searched using the keywords such as "AI in Sri Lankan education," "sustainability in university education," and "AI and student engagement." Only peer-reviewed articles and conference proceedings published between 2018 and 2023 were included to ensure relevance. Articles that focused on the implementation of AI in higher education within Sri Lanka or similar contexts were included whereas studies that did not directly address AI applications or the studies that were not conducted in higher educational settings were excluded. Data from selected studies were extracted, categorized, and synthesized based on recurring themes, such as AI's impact on learning personalization, resource management, and student retention. Ten studies meeting the criteria were analyzed in depth, and the findings were compiled into thematic categories.

2.1 Literature Review

The integration of Artificial Intelligence (AI) in higher education has garnered significant attention globally due to its potential to enhance learning outcomes, streamline administrative processes, and

promote sustainable educational practices. The literature review provides a comprehensive summary of the key findings as follows.

A study by Gamage (2018) emphasizes how AI can optimize budget allocations by predicting resource needs based on previous records. This predictive capability supports sustainable budgeting practices which can free up funds for other educational initiatives. The efficient allocation of resources contributes to a more sustainable learning environment where students and faculty benefit from a stable and well-supported educational infrastructure.

AI tools are instrumental in helping universities manage limited resources more effectively. A study by Wijesekera et al. (2019) discusses the application of AI in monitoring classroom utilization which aids in resource allocation by identifying which facilities are most used and when. This data helps universities plan resource allocation better, ensuring that students have access to necessary resources while minimizing waste.

One of the most impactful applications of AI in Sri Lankan universities is the creation of personalized learning experiences, which cater to individual needs and preferences of students. According to Perera et al. (2020), AI-powered adaptive learning platforms allow content to be tailored to each student's pace and the level of understanding, promoting more effective engagement and knowledge retention. These systems enable students to revisit challenging concepts, advancing at their own speed, which is especially beneficial in large classroom settings.

Intelligent tutoring systems (ITS) have shown promise in assisting students with skill-intensive subjects, such as engineering and computer science. Gunasekera et al. (2020) report that ITS applications help students practice and master complex skills through continuous feedback and adaptive learning paths. For Sri Lankan universities, ITS can be an invaluable resource in equipping students with market-ready skills, thus enhancing their employability upon graduation.

Although AI presents many benefits, its implementation in Sri Lankan universities faces several challenges. Bandara and Jayasinghe (2020) point out that limited infrastructure, funding constraints, and lack of technical expertise are major obstacles to successful adoption of AI technologies. Addressing these challenges requires substantial investment in digital infrastructure and training programs to equip faculty and staff with skills necessary to work with AI systems.

Additionally, concerns regarding data privacy and the ethical use of AI have emerged as important considerations. Establishing robust policies and regulatory frameworks is essential to ensure that AI is implemented in a way that aligns with ethical standards, protecting student data and promoting responsible AI use.

Fernando and Silva (2021) highlight that AI-based learning tools have positively influenced student engagement by creating interactive learning environments. By integrating AI tools that respond to student feedback and learning behaviors, universities can promote inclusivity and equity, ensuring that all students, regardless of their initial competency levels, receive support tailored to their needs.

AI has also proven useful in the realm of administrative support. Fernando and Silva (2021) describe how universities in Sri Lanka are implementing AI for automating admissions processes, handling queries, and managing grading systems. Automation of these tasks reduces the administrative burden on faculty and staff, allowing them to focus more on direct academic support and research.

Administrative AI applications lead to faster processing time and a reduction in errors, which enhances operational efficiency. Efficient administration is critical to sustainability, as it allows universities to manage large volumes of students without sacrificing service quality, ensuring that the institution can scale as student numbers grow.

AI tools that analyze student feedback and learning outcomes can be valuable for faculty development. According to De Silva et al. (2021), these tools allow faculty to receive data-driven insights into their teaching effectiveness. AI-driven feedback systems can highlight areas where

students struggle the most, enabling faculty to adjust their instructional methods to improve learning outcomes.

AI-driven predictive analytics are helping universities in Sri Lanka identify students who may be at risk of dropping out. Kumar and Rajapaksha (2022) show that predictive models using student data, such as attendance, grades, and engagement metrics can identify patterns associated with poor academic performance. Early intervention for at-risk students can significantly improve retention rates and ensure that students have the support they need to succeed academically.

This approach not only benefits students but also contributes to sustainability of educational institutions by reducing dropout rates and fostering a culture of support and encouragement. Lower dropout rates lead to better resource utilization and a more stable student population which are critical components of sustainable university systems.

The use of ITS in technical fields ensures that students gain hands-on experience and practical knowledge, which is essential for building a future-ready workforce. This prepares students for the competitive job market and aligns university education with industry standards, promoting long-term educational sustainability.

3. RESULTS AND DISCUSSION

The review of the ten selected studies highlights several key findings regarding the impact of AI on education. AI tools significantly enhance learning experiences by personalizing content which improves student engagement and knowledge retention. Furthermore, AI facilitates efficient resource allocation, an essential factor in managing limited educational resources. Predictive analytics driven by AI play a crucial role in identifying at-risk students, ultimately aiding in improving retention rates. Intelligent tutoring systems (ITS) also contribute to skill development, helping students acquire practical abilities necessary for career readiness. Additionally, the automation of administrative tasks through AI enhances operational efficiency and reduces errors. Lastly, AI-driven feedback mechanisms assist faculty in adapting and refining their teaching strategies, fostering a continuous learning environment.

This document also notes significant challenges in implementing AI across Sri Lankan universities. Infrastructure limitations, funding shortages, and the need for staff training present barriers to fully realizing AI's potential, as emphasized by Bandara and Jayasinghe (2020). Addressing these issues will require strategic investment in digital infrastructure and capacity-building initiatives. These steps are essential to enable both faculty and administrative staff to effectively leverage AI in their workflows and teaching practices.

Furthermore, ethical considerations related to AI use, particularly regarding data privacy, require attention. Universities must develop policies to safeguard student information and regulate AI deployment to prevent misuse. As De Silva et al. (2021) argue, establishing these ethical frameworks is crucial for creating a responsible AI environment that respects student rights while fostering technological advancement. Furthermore, this has shown remarkable potential in transforming higher education in Sri Lanka, the discussion underscores that sustained efforts in infrastructure development, policy formulation, and ethical considerations are necessary for AI to be a force for sustainable educational innovation.

4. CONCLUSION

AI-driven solutions play a crucial role in enhancing student learning through personalized educational experiences and optimizing resource management by efficiently allocating limited resources and reducing waste. AI also supports retention of students through predictive analytics. Additionally, intelligent tutoring systems (ITS) help students gain practical skills relevant to the job market, aligning educational outcomes with industry demands and strengthening students' career prospects upon graduation. On the administrative side, AI-driven automation streamlines processes

such as admissions, grading, reducing administrative burden on staff and improving service efficiency.

AI-driven technologies play a pivotal role in transforming higher education by fostering personalized learning, enhancing student engagement, optimizing resource allocation, and supporting administrative functions through intelligent tutorial systems. For the Institute of Technology University of Moratuwa and other higher education institutions, these findings underscore the immense benefits that AI can offer in shaping a more sustainable and efficient educational ecosystem. Despite these advantages, challenges remain, such as limited infrastructure, funding constraints, and the need for extensive training programs to ensure successful implementation.

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ASSESSING THE ROLE OF INTERACTIVE SMART BOARDS IN ENHANCING SUSTAINABILITY IN PRIMARY EDUCATION: A REVIEW OF IMPLEMENTATION STRATEGIES AND EDUCATIONAL OUTCOMES IN SRILANKAN CLASSROOMS

P.N.T. Pathirana[*]

Institute of Technology University of Moratuwa, Sri Lanka

nadeesha8thamali@gmail.com[*]

ABSTRACT: This study was conducted to evaluate the outcomes of interactive smart boards in primary education in Sri Lanka focusing on their effectiveness in the teaching and learning process as well as their sustainability. The study utilized a combination of quantitative surveys and qualitative interviews with teachers and students from various schools. The results indicated that smart boards play a vital role in enhancing student interaction through interactive, multimedia-rich lessons that cater to different learning modes and promote collaboration. Findings highlight that these interactive smartboards facilitate more dynamic lessons and provide broader access to education materials. Furthermore, the findings underscore smart boards as a tool for educational sustainability that encourage reduced paper usage and more efficient resource management. However, the research reveals some downsides, particularly regarding technical difficulties and the importance of adequate training. There is a risk that teachers may become overly reliant on technology. Overall, the research finds that smart boards provide significant benefits - nearly 90% for education and sustainability in Sri Lankan primary schools. Yet, these advantages are often frustrated by technical issues as well as inadequate training. Despite the challenges associated with using smart boards to modernize education and adopt sustainable practices, they present significant opportunities for achieving these goals.

Keywords: primary education, smart board, sustainability in education, technology

1. INTRODUCTION

Over the last several years, the growth of information and communication technologies (ICT) in education has become more and more critical in determining the methods of teaching and learning. Among the various technologies in use today, the interactive smart board (ISB) stands out as one of the most revolutionary devices. Smart boards were first used in education in the late 1990s (Beeland, 2002). These devices, apart from creating an exciting learning atmosphere, are likely to improve the effectiveness of learning processes. With the further development of educational facilities in Sri Lanka, it is essential to explore how such technologies can be utilized in primary education to promote sustainable development. Effective usage of any technology relies on several factors, one of which is teacher proficiency. If a teacher does not know how to use a SB, s/he will not use it during the learning process)Adagideli, 2019).

This study looks at how interactive smart boards play a key role in boosting sustainability in primary classrooms in Sri Lankan. In this context, sustainability not only means keeping educational practices going for a long time but also the ability to help students learn and adapt in our rapidly changing digital world. The research investigates how schools implement these smart boards and the outcomes they achieve. Its aim is to evaluate the effectiveness of these boards and their potential to enhance the sustainability of teaching practices. SB with thier multiple functions offer numerous benefits for education. These include interactive lessons, immediate feedback and collaborative learning. However, to maximize their effectiveness in classrooms, robust planning and support systems are essential.

There are many advantages of SB. One significant benefit is the ease of connecting smart boards to the internet, allowing access to information from various resources. This internet connectivity enables teachers to obtain expert opinions from field specialists around the world without needing to be in the same location. Additionally, teachers can scan any part of a textbook and display it on the screen using the smart board, which saves both time and resources (Adagideli, 2019). The touch

screen technology of smart boards offers greater flexibility in presenting materials. It provides a sample workspace for hands-on activities with various multimedia resources, featuring a display surface large enough to encourage high levels of student interaction (Abdullah, 2020). To meet the evolving needs of Sri Lankan schools, the number of smart classrooms must be increased (Vijayabaskar, 2022).

This study will focus on the primary section of Sri Lankan schools examining the integration of interactive smart boards into teaching methods and their impact on various aspects on learning. The significance of this study lies in its potential to make us understand how interactive smart boards can be used to promote sustainability in schools. By analyzing current practices, challenges, and successes, this research hopes to give useful insights to teachers, decision-makers and stakeholders involved in incorporating technology into classrooms. In brief, this study aims to understand the role of interactive smart boards in enhancing sustainability for primary education in Sri Lanka. The study aims to derive recommendations from a comprehensive assessment of implementation strategies and educational outcomes that can facilitate the successful integration of this technology offering an enhanced, sustainable academic experience for students in the long run.

This study aims to achieve two main objectives:
 i. To examine the effectiveness of interactive smart boards in primary education settings in Sri Lanka.
 ii. To identify the challenges and facilities associated with the use of ISBs in primary education.

2. METHODOLOGY

The sample for the study consisted of 40 primary school teachers working in different districts in Sri Lanka. These teachers participated voluntarily, and the sample predominantly included individuals aged between 25 and 40 years. Additionally, 10 students comprising 5 males and 5 females were selected from grade five students in Sri Lankan primary schools. Primary data for this study was collected through a google questionnaire form which focused on collecting data in four identified sections:-(1) Demographic Information (2) Implementation strategies (3) Student interaction and Teacher Performance (4) Challenges and Recommendations. At the end of the study, interviews were conducted to gather opinions from both students and teachers. A total of 30 teachers participated in the quantitative survey while 10 teachers participated in the interview. The questions were designed based on expert assessment. The questionnaires were created prior to conducting a trial application with a primary school teacher. Two qualitative interviews were conducted for teachers and students. Teachers' and students' responses to the questionnaire were analyzed using frequencies and percentages. The responses were analyzed using Microsoft Office and Excel 365 where percentages were calculated and transformed into tables to enhance readability.

3. RESULTS AND DISCUSSION

In this section, the responses of teachers to the quantitative and qualitative survey questionnaires are discussed.

3.1 Quantitative Survey for the teachers
3.1.1 Demographic Information
Although 90% of schools have smart boards, only 56.6% use them for primary students. Among those, only 17.9% of teachers use them daily, 25% use them weekly, 3.6% use them monthly, and 17.9% of teachers rarely use them.

3.1.2   Implementation Strategies

According to data, only 6.7% of teachers receive training on smart boards weekly, 46.7% of teachers receive rarely. While 92.6% of teachers rated the availability of educational resources as good, 3.7% reported having limited access to resources. Additionally, 70.4% of teachers expressed satisfaction with technical support while 7.4% rated it as average and 22.2% reported being dissatisfied.

3.1.3   Student interaction and teacher performance

According to this section of the research, 96.7% of teachers believe that smart boards will improve student academic performance. Additionally, 95.5% of teachers feel that smart boards enhance student interaction in their classrooms. Teachers also report that 96.6% see a positive impact on student achievement and 96.6% have effectively used smart boards to teach environmental awareness and sustainability concepts.

3.1.4   Challenges and Recommendations

Regarding challenges, 89.7% of teachers believe that smart boards help develop students' critical thinking and problem-solving skills. However, 10.3% disagree with it. Many teachers report experiencing internet issues when using smart boards, and even when their school has a smart board, it is often not utilized.

3.2   Qualitative Interview for Teachers

During qualitative interviews with teachers, they indicated that paper usage will be reduced by nearly 90% using smart boards leading to more efficient teaching. They noted that nearly 80% might become too reliant on technology while around 20% disagreed with this perspective. Furthermore, teachers believe that smart boards will enhance nearly 90% of students' understanding of sustainability concepts and increase about 80% of students' knowledge of sustainable practices.

3.3   Qualitative Interview for Students

Interviews with 10 students revealed significant insights into the impact of Interactive Smart Boards. Nearly 90% of students reported that they actively participated in lessons when ISBs were utilized indicating a market improvement compared to traditional teaching methods. Students were also informed that interactive and multimedia-rich lessons enhance their overall learning experience.

4.   CONCLUSION

This research will provide valuable insights into the role of interactive smart boards in enhancing sustainability in primary education. Findings suggest that SB is beneficial for teachers to teach and for students to learn. Therefore, smart boards need to be popularized in towns and villages schools.

Accordingly, infrastructure for the internet needs to be provided for the places where the internet infrastructure is absent or little. The internet infrastructure in schools needs to be improved. With a high-speed internet infrastructure, more online course activities can be applied on the smart board. SB in schools should be checked regularly to avoid crashes. As a result, interruptions in education in schools where the smart board is used can be prevented. One important point is that primary school teachers cannot use ISB professionally. Teachers may be supported with training by the experts on using smart boards. In-service training courses can be popularized and held frequently in order to increase the level of using a smart board. Moreover, lesson contents can be developed for teachers to make a course presentation on SB. By this way, teachers do not spend more time to prepare material for the SB.

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THE ROLE OF SCOIAL MEDIA IN PROMOTING INTERDISCIPLINARY SUSTAINABILITY EDUCATION

K.A.D.P. Lankika[1*] and K.H.N. Yasanga[2]
[1,2]Institute of Technology University of Moratuwa, Sri Lanka
pathini.kuruppu@gmail.com[1*], nipunayes@gmail.com[2]

ABSTRACT: Social media has become a crucial tool for advancing interdisciplinary sustainability education by raising awareness, sharing knowledge, and fostering collaboration among students and educators across various fields. Its primary strength lies in its broad reach, especially among younger audiences engaged with digital platforms. Campaigns like #ClimateStrike demonstrate how social media can mobilize communities and highlight urgent sustainability issues. By facilitating rapid and extensive information dissemination, social media encourages dialogue and interaction, creating a community that supports interdisciplinary collaboration and resource sharing. Furthermore, social media's diverse content formats—videos, podcasts, infographics—cater to various learning styles, enhancing the understanding of complex sustainability concepts and promoting active engagement. However, challenges such as limited social media literacy among educators and resource constraints can impede effectiveness. To maximize social media's potential in sustainability education, it is crucial to invest in training for effective communication strategies. Social media also showcases successful sustainability initiatives, inspiring others to adopt similar practices and engage in collaborative projects to address sustainability challenges. Despite these benefits, it is important to systematically evaluate the impact of social media efforts to measure their effectiveness in achieving educational and behavioral outcomes related to sustainability. In conclusion, social media significantly enhances interdisciplinary sustainability education by improving awareness, facilitating knowledge sharing, and fostering collaboration. Addressing challenges such as social media literacy and resource allocation will help educational institutions leverage this tool effectively, preparing students to confront future sustainability challenges.

Keywords: awareness, collaboration, interdisciplinary sustainable education, knowledge sharing, social media

1. INTRODUCTION

Social media has emerged as a powerful tool in promoting interdisciplinary sustainability education by raising awareness, enabling knowledge sharing, and encouraging collaboration across various academic and professional fields. Its importance lies in its ability to transcend traditional educational boundaries, fostering interactions between disciplines such as environmental science, economics, technology, and the social sciences. This interdisciplinary approach is crucial for addressing global sustainability challenges, which require collective solutions informed by multiple perspectives. Social media fosters an interactive environment where educators, students, and professionals can exchange resources, insights, and research in real-time, thus creating a dynamic learning ecosystem. The objective of this study is to examine how social media can further advance interdisciplinary sustainability education. Specifically, this research will evaluate the effectiveness of social media in facilitating communication across various disciplines, promoting active collaboration, and disseminating complex sustainability concepts in accessible formats. Through an analysis of existing literature and relevant case studies, this study aims to uncover best practices for using social media in educational settings and identify challenges, such as digital literacy gaps and resource limitations, that may hinder its effective implementation. Ultimately, this research seeks to offer strategic recommendations for integrating social media into sustainability education frameworks, preparing students to engage with pressing environmental and societal issues through a more connected and interdisciplinary lens.

2. METHODOLOGY

This study employs a mixed methods approach to explore the role of social media in promoting interdisciplinary sustainability education. The research methodology includes both qualitative and quantitative analyses to ensure a comprehensive understanding of the subject.

Literature Review: A systematic review of existing literature was conducted to identify studies that have explored the use of social media in educational contexts, particularly in sustainability education. Peer-reviewed journals, academic papers, and case studies from various disciplines were reviewed to understand best practices and current challenges in integrating social media into educational frameworks.

Case Study Analysis: A selection of case studies was analyzed to examine real-world applications of social media in interdisciplinary educational settings. Case studies were chosen based on their relevance to sustainability education and their demonstrated impact on awareness, knowledge sharing, or collaboration. Platforms like Twitter, Instagram, and YouTube were evaluated for their role in facilitating these outcomes.

Survey: A survey was distributed to educators, students, and sustainability professionals to gather insights on their use of social media in sustainability education. The survey consisted of both closed and open-ended questions aimed at understanding how these stakeholders utilize social media for interdisciplinary learning and what challenges they encounter in this process.

Data Analysis: The quantitative data collected from the survey was analyzed using statistical methods, including descriptive statistics and correlation analysis, to assess the relationships between social media usage, interdisciplinary collaboration, and educational outcomes. The qualitative data from the open-ended survey responses and case study reviews were analyzed using thematic analysis to identify recurring themes and challenges related to social media integration in sustainability education.

3. RESULTS AND DISCUSSION

The mixed-methods approach yielded significant insights into the role of social media in promoting interdisciplinary sustainability education. The literature review identified over 50 relevant studies that highlighted the effectiveness of social media in enhancing engagement and knowledge sharing among diverse educational stakeholders. Key findings from the literature indicate that platforms like Twitter and Instagram are particularly effective in mobilizing younger audiences and facilitating real-time discussions on sustainability issues.

The case study analysis revealed three prominent themes: increased awareness, enhanced collaboration, and improved resource sharing. For instance, one case study involving a university's use of Instagram to showcase sustainability projects resulted in a 40% increase in student participation in related initiatives. Another case study demonstrated how Twitter was utilized to connect students from different disciplines for collaborative projects, leading to innovative solutions for local environmental challenges.

Survey results from 100 participants (educators, students, and sustainability professionals) indicated that 78% of respondents believe social media enhances their learning experience in sustainability education. However, 62% reported facing challenges related to digital literacy and resource availability. Correlation analysis showed a positive relationship between frequent social media use and perceived effectiveness in interdisciplinary collaboration.

The findings underscore the transformative potential of social media in fostering interdisciplinary sustainability education. The literature review supports the notion that social media can transcend traditional educational boundaries, creating a dynamic learning environment where diverse perspectives converge. Notably, the case studies illustrate practical applications of social media that

have successfully engaged communities and facilitated collaborative learning. However, the challenges identified in the survey highlight critical areas for improvement. The digital literacy gap among educators and students poses a significant barrier to effectively utilizing social media for educational purposes. Addressing this gap through targeted training programs could enhance the overall effectiveness of social media initiatives in sustainability education.

Moreover, while the positive correlation between social media usage and collaborative outcomes is promising, it is essential to systematically evaluate these initiatives' long-term impact on educational and behavioral outcomes related to sustainability. Future research should focus on longitudinal studies to assess how sustained engagement with social media influences students' understanding and commitment to sustainability issues.

4. CONCLUSION

This study highlights the significant role of social media in advancing interdisciplinary sustainability education by enhancing awareness, facilitating knowledge sharing, and fostering collaboration among students and educators. The mixed-methods approach employed in this research revealed that social media platforms effectively engage diverse audiences, particularly younger generations, in critical sustainability issues.

The literature review and case study analysis demonstrated that social media can create dynamic learning environments where interdisciplinary dialogue flourishes, leading to innovative solutions for complex sustainability challenges. Survey findings further confirmed that a majority of participants recognize the benefits of social media in their educational experiences, although challenges related to digital literacy and resource availability persist.

Aligned with the objectives of this study, the results emphasize the need for targeted training programs to improve digital literacy among educators and students. By addressing these challenges, educational institutions can leverage social media more effectively, ultimately preparing students to engage with pressing environmental and societal issues through a connected and interdisciplinary lens. This research contributes valuable insights into best practices for integrating social media into sustainability education frameworks, paving the way for future studies to explore its long-term impact on educational outcomes.

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EFFECTIVENESS OF USING VIRTUAL LABORATORY SIMULATIONS IN PHYSICS EDUCATION BY COMPARING THE ACCURACY OF GRAVITATIONAL ACCELERATION RESULTS

M. N. V. Fernando[1*], D. H. H. P. Dassanayake[2] and M. D. B. Madhuwanthi[3]
[1, 2, 3] Faculty of Engineering, NSBM Green University, Sri Lanka
nipuni.f@nsbm.lk[1*], hiruni.d@nsbm.lk[2], buddhika.m@nsbm.lk[3]

ABSTRACT: Conducting laboratory experiments is crucial for comprehending physics theories and their practical applications at any educational level. Virtual laboratory experiments have become more popular because of developments in technology. These experiments offer numerous benefits over traditional physical laboratories, including increased flexibility, cost-effectiveness, accessibility, and safety. When considering these advantages, it is important to take into consideration how accurate virtual laboratories are in enhancing students' educational levels when compared to physical laboratories. Hence, this study mainly aims to observe how the quality of physics education at NSBM Green University, Sri Lanka, can be enhanced by introducing virtual laboratories. To determine the gravitational acceleration (g), 29 Engineering Foundation students participated in the Simple Pendulum Oscillation Experiment as part of their Physics course. The PhET platform was used to conduct the virtual laboratory, while the physics lab was used to conduct the physical laboratory. According to the results obtained in both physical and virtual laboratories, it was observed that the mean, median and mode 'g' values obtained in both methods are closer to the actual gravitational acceleration value. But the 'g' values obtained from the physical laboratory consists of higher variability and a wide range of results. This indicates that, in comparison to physical laboratories, virtual laboratories provide more consistent and stable results with less variability. But physical laboratories help the students to improve their critical thinking and problem-solving abilities and to understand theoretical concepts. Therefore, this study shows that a combination of physical and virtual experiments in a variety of other disciplines with different kinds of virtual platforms can be further expanded for the advancement of educational technology.

Keywords: oscillation experiment, physical laboratories, physics education, virtual laboratories

1. INTRODUCTION

Virtual laboratories have gained popularity in physics education as technology continues to advance. It encompasses real-world problems and is more attractive because studies mainly focus on various aspects such as student engagement, learning outcomes, and practicality (Alsharif, 2022). Virtual laboratories give more chances to become familiar with the platform, increase confidence and can handle more complex laboratories (Umukozi, Yadav, & Bugingo, 2023). Virtual laboratories are easier, simpler, more interesting and can handle simultaneous participation by multiple students compared to traditional hands-on laboratory experiments (Mihret, Alemu, & Assefa, 2022) and have fewer restrictions on how they can conduct the laboratory according to their availability and requirements (Asiksoy, 2023). However, considering these factors, academics must identify the accuracy of the virtual laboratories rather than performing in conventional laboratories. To analyze the accuracy of the results, this study was conducted using a simple pendulum oscillation physics experiment. The main aim of this study is to enhance the quality of educational technological advancement by implementing virtual laboratories of physical science education at NSBM Green University, Sri Lanka.

2. METHODOLOGY

A sample of 29 Engineering Foundation students studying Physics-1 as a core module of their Foundation Program at the Faculty of Engineering, NSBM Green University, participated in this laboratory experiment. Each student performed a physical experiment in the physics laboratory and a virtual experiment using the PhET platform. For both laboratories, all the parameters were set as common (Except environmental factors); the weight of the simple pendulum was 0.5 kg, and lengths (L) of the pendulum were 0.4 m, 0.5 m, 0.6 m, 0.7 m, 0.8 m, and 0.9 m. The time-period (T) was measured and recorded by making 25 oscillations for each length. Obtaining the results of the virtual laboratory, the T^2 against L graph was plotted using Microsoft Excel 2016, and results obtained from the physical laboratory, a graph was plotted manually to determine the gradient of the graph. During

the physical laboratory session, manual graph plotting allowed students to obtain hands-on experience with traditional data analysis techniques with graph interpretation. In the virtual laboratory, Microsoft Excel's efficiency aligned well with the virtual lab environment, making it a suitable tool for data analysis. Then the gravitational acceleration was calculated for both virtual and physical laboratories and both values were submitted as a lab report along with a questionnaire. Using these test results, descriptive analysis including mean, median, mode, and standard deviation was calculated to summarize the data from IBM SPSS Statistics. Additionally, t-test was employed to compare the effectiveness of physical laboratory result versus virtual laboratory result. Fig. 1 shows the detailed methodology adopted for the study.
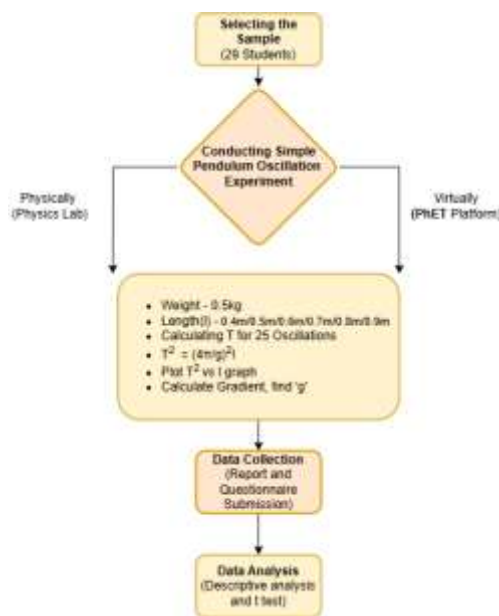
Fig. 1. Flow Chart of Methodology

3. RESULTS AND DISCUSSION

Fig. 2 shows the results obtained from the students' questionnaire. Based on these results, all the students have responded that physical laboratories have improved their critical thinking and problem-solving abilities more than virtual laboratories. 59% of students stated that physical laboratories helped them in understanding theoretical concepts, while 41% of students said that virtual laboratories are good in understanding the theoretical concepts. Compared to virtual laboratories, physical laboratories are more time-consuming. In terms of repeatability, 76% voted that virtual laboratories are more repeatable than physical laboratories. When comparing the obtained gravitational acceleration values, 73% of students received more accurate values for 'g' from the virtual experiment, and 27% of students obtained accurate 'g' values from the physical experiment.
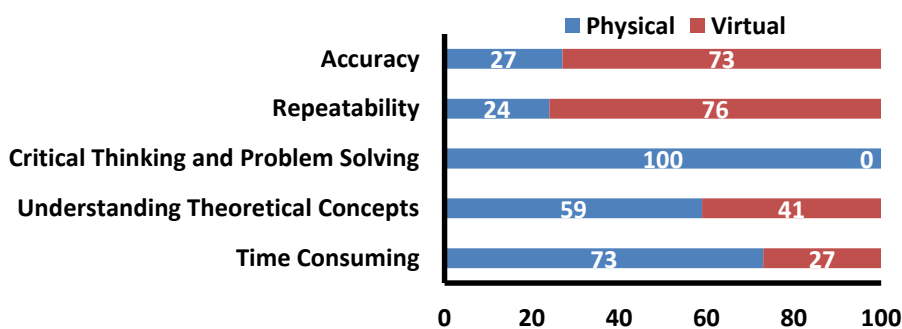
Fig. 2. Students' Survey Results on Physical and Virtual Laboratory Experiments

Table 1. Results of Descriptive Analysis

Variable	No of Students	Mean	SE Mean	St.Dev	Minimum	Median	Maximum	Mode	P Value
Physical Lab	29	9.8655	0.1136	0.6117	7.900	9.860	12.260	9.860	0.839
Virtual Lab	29	9.8417	0.0249	0.1341	9.410	9.860	10.300	9.870	0.839

The standard value of the acceleration due to gravity is 9.80665 m/s². When comparing the percentage error between the actual and experimental results, the physical laboratory has 0.60% and the virtual laboratory has 0.36%, which shows that virtual laboratories provide more accurate results than physical laboratories. The mean gravitational acceleration of physical laboratory was 9.8655 m/s² with a standard deviation of 0.6117, which shows relatively higher variability in the data set, while 9.8417 m/s² for virtual laboratory has a lower standard deviation of 0.1341. According to the analysis, the results obtained from virtual laboratory were more consistent compared with physical laboratory.

When considering the range of the values, the physical laboratory has a wide range of gravitational acceleration values, where minimum is 7.90 m/s^2 and maximum is 12.26 m/s^2 (Fig. 3). This higher range indicates that some data of the set has dropped off from the exact value. This may cause human errors, atmospheric errors and instrumental errors. Compared with virtual laboratory, the minimum value is 9.41 m/s^2 and maximum value is 10.30 m/s^2 reflecting the controlled lab environment of the virtual laboratory. Both physical and virtual laboratories have the same median value of 9.860 m/s^2, while the mode for virtual and physical laboratories are 9.87 m/s^2 and 9.86 m/s^2 respectively. That indicates that both data sets are quite similar and most of the values are clustering around each other. The p value of t-test which is 0.839 much greater than the common significance level threshold (0.05) and it fails to reject the null hypothesis. Therefore, this proves no statistically significant difference can be identified between the means of two laboratories. This study can be expanded to include more physical and virtual experiments in different disciplines by using different virtual experiment platforms for improved results.
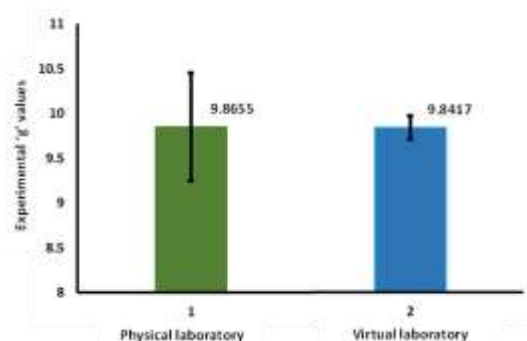
Fig. 3. Comparison between Physical and Virtual Experimental Results

4. CONCLUSION

The gravitational acceleration value measured by physical and virtual laboratories for the simple pendulum experiment shows that both laboratory experiments provide accurate results, while the virtual laboratory provides more consistent and reliable measurements with less variability. Moreover, compared to the virtual laboratory, the physical laboratory consists of higher variability and a wide range of results due to real-world experimental conditions and errors caused by humans and equipment. Both laboratory types exhibit similar patterns, with comparable median and mode values. This study proves that virtual laboratories are more stable and have a reproducible learning environment, while physical laboratories provide real-world environmental attributes to help students understand theoretical concepts. Therefore, a combination of both methods can enhance the learning environment, gaining experience, leading to better understanding skills and practical skills, and improving the quality of education at NSBM Green University.

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COGNOTUTOR: A SUSTAINABLE SOLUTION FOR IMPROVING METACOGNITIVE SKILLS

A.U.P. Athukorala[1*], D. Fernando[2], and C. Wijeratne [3]
[1]Institute of Technology University of Moratuwa, Sri Lanka
[2]Sinagpore University of Science and Technology, Singapore
[3]University of Colombo, Sri Lanka
uthpalap@itum.mrt.ac.lk[1*], dileepa_fernando@sutd.edu.sg[2], cjw@maths.cmb.ac.lk[3]

ABSTRACT: Improving self-regulated learning among students is more sustainable when transferable skills, such as metacognitive skills, are developed. Many students face challenges in learning due to lack of effective self-regulated learning strategies. This study proposes the design of CogNoTutoR, a web-based tool aimed at enhancing metacognitive skills in mathematical problem-solving through personalized feedback. The system employs a validated 12-item questionnaire (Content Validation: 0.9; Reliability [Ordinal Alpha]: 0.89) to assess students' initial metacognitive levels and generate tailored feedback. A pilot study involving mathematics lecturers, students, and interface designers is planned to refine the system further. Future developments include the integration of automated grading and the expansion of the application to multidisciplinary contexts, supporting sustainable educational practices.

Keywords: mathematics, metacognitive skills, sustainability, transferrable skills,

1. INTRODUCTION

With the rapid growth of population, non-renewable resources are not growing but stagnating. Sustainability focuses on minimizing waste and pollution, expanding the life cycle of products and regenerating natural systems (Gavkalova et al., 2023). Education systems can contribute to this process in two ways:

i. Students can be educated on sustainable practices and
ii. Teaching and learning process can be designed in more sustainable way.

The meaning of metacognition is "knowing about your own thinking process" (Ozturk, 2017). Metacognition is divided into two components: metacognitive knowledge and metacognitive skills (Schuster et al., 2020). Among these, metacognitive skills are identified as transferrable and task-general (Schuster et al., 2020). Improved metacognitive skills can be applied in a variety of contexts, such as reading exercises or laboratory experiments. Hence, improving metacognitive skills in students is more economic and sustainable as it aligns with one of the major principals of sustainability "reuse".

There are feedback systems designed for improving metacognitive skills in subjects such as mathematics, biology and basic science. MeMo Tutor is a web application integrated with the Moodle for Linear Algebra lessons. It generates personalized feedback and supports account creation for students and teachers, promoting reusability. However, it is limited to the Bahasa Indonesia language and does not assess metacognitive skills (Martha et al., 2019). Elbasri (2019) and colleagues designed a metacognitive agent system that measures metacognitive skills using questionnaires and provides personalized feedback. The system is standalone and lacks reusability and collaboration features (Elbasri et al., 2019). MetaTutor, a standalone application, uses four agents to provide metacognitive feedback, focusing on self-regulated learning (SRL) in blood circulation. While effective for SRL development, it lacks broad subject applicability and collaborative features. Another standalone system was designed to assess the impact of metacognitive scaffolding on self-efficacy, metacognition, and achievement in e-learning. It supports auto-grading and student goal setting but is limited to Colombian language mathematical problem-solving, hindering its adaptability to broader use (Azevedo et al., n.d.). By reviewing existing work, it is clear that available systems do not integrate sustainability in their designs.

The primary objective of this study is to present the design of CogNoTutoR and its feedback mechanism, developed to provide targeted support for students with varying metacognitive skills. Future developments will focus on incorporating features for automated grading, expanding subject-specific modules, and conducting a comprehensive pilot study involving students, mathematics lecturers, and interface designers to refine CogNoTutoR's usability and effectiveness as a sustainable educational tool.

2. METHODOLOGY

The CogNoTutoR system is a web-based tool designed to foster metacognitive skill development, particularly within mathematical problem-solving contexts, by generating personalized feedback tailored to individual students' needs. By incorporating a structured, phase-based feedback approach that includes planning, monitoring, and evaluation, CogNoTutoR aims to enhance students' engagement in self-regulated learning.

2.1 System Structure and Technology Stack

CogNoTutoR employs a robust technology stack designed for scalability and ease of maintenance. PHP (Hypertext Preprocessor) and the Laravel framework drive the backend infrastructure, handling user management, feedback generation, and questionnaire analysis, while the frontend is powered by Bootstrap, ensuring a responsive, accessible user experience. MySQL serves as the database system, storing student responses and feedback for future reference. ChatGPT, integrated through API, provides question-specific feedback by generating responses that align with the goals of each learning phase.

2.2 Feedback Mechanism and Questionnaire

A validated 12-item metacognitive skills questionnaire ((Athukorala et al., 2024) is central to CogNoTutoR's user identification. This questionnaire was designed based on the systematical observations used in thinking aloud protocol in mathematical problem solving (Jacobse & Harskamp, 2012). Students complete this questionnaire upon initial sign-in, which measures essential aspects of metacognitive skills. Responses, stored securely within the system, inform feedback generation, with specific attention to areas that need development. For instance, responses rated as "Sometimes" or "Almost Never" receive targeted feedback in yellow color, while the option "Often" are reinforced in green color.

The questionnaire is structured to provide insights across several domains: self-awareness and planning, monitoring and progress checking, evaluation and reflection.

2.3 Phased Feedback Model

CogNoTutoR's feedback model is structured into three phases, supporting self-regulated learning by delivering context-specific prompts throughout the problem-solving process:

1. **Planning Phase**: Initial feedback guides students to carefully read the problem, set goals, and strategize their approach. For instance, when faced with combinatorial questions like "How many ways can the letters in 'MISSISSIPPI' be arranged?", the system might prompt students to focus on reading the question thoroughly and identifying key variables, aligning with foundational planning skills.

2. **Monitoring Phase**: As students' progress, feedback is geared towards ensuring they remain on track. Prompts may encourage students to revisit earlier steps or verify intermediate calculations, enhancing their ability to self-correct.

3. **Evaluation Phase**: After a solution submission, students receive evaluation feedback designed to foster self-reflection, such as assessing the solution's accuracy and considering alternate methods. This phase includes timed prompts that guide students in reviewing their answers before proceeding to the next question.

CogNoTutor is a password protected application. Teachers and students should create a profile when they first login to the application and they should use their username and password every time they log. This limited access prevents the system from unauthorized access. Teachers can add tutorials, view students' metacognitive skills, add marks and view marks of the students. Students can work on tutorials, view marks for each tutorial and try metacognitive skills level questionnaire.

Currently, CogNoTutoR is tailored to mathematical problem-solving, specifically within the domain of number theory. To broaden the tool's applicability, future updates could incorporate modules for additional subjects. And potential issues that can occur due to AI generated feedback is planned to be addressed and possible solutions are to be implemented as a future work. Furthermore, a pilot study involving usability testing and user satisfaction surveys is planned, which will provide empirical data to assess the system's effectiveness in fostering metacognitive skills. Preliminary findings from this study will be integrated into future iterations of the system to refine and validate feedback mechanisms, enhancing CogNoTutoR's educational impact.

3. DISCUSSION

CogNoTutoR is a tool that provides adaptive feedback to improve students' metacognitive skills in math problem-solving, focusing on self-regulated learning. By utilizing a validated metacognitive skills questionnaire, it evaluates and monitors students' advancement, allowing teachers to give customized guidance on time. The digital system's design reduces paper consumption, supports sustainability objectives, and promotes reuse of resources to enhance efficiency and cognitive ease. CogNoTutoR's structured feedback emphasizes planning, monitoring, and evaluation to help students refine problem-solving approaches and develop transferable metacognitive skills for use in multiple subjects. This adaptability supports broader applications; as additional modules can extend their benefits to other learning areas. Future enhancements include usability testing and privacy safeguards, ensuring that the system is both effective and ethical.

4. CONCLUSION

This paper presents CogNoTutoR, a web application that aims to enhance metacognitive skills for problem-solving using mathematics as its subject area. Metacognitive learning can be fostered through the structured nature of mathematical problem-solving tasks, which encourages learners to develop their own level of self-regulation and reflection (Kusaka & Ndihokubwayo, 2022). The application starts with the validated 12-item questionnaire, which is used to assess students' metacognitive skill levels and provides students tailored feedback along with the meta-cognitive prompts, problem-specific hints through ChatGPT for adaptive responses in real-time. This way CogNoTutoR encourages resource reuse, minimizes cognitive waste and harmonizes with sustainable learning.

As an adaptive tool, CogNoTutoR can be scaled to accommodate additional subjects, extending its benefits across diverse educational contexts. This scalability ensures that students can apply and reinforce metacognitive skills in multiple domains, supporting self-regulated learning over time. Moving forward, planned usability testing and empirical validation will provide critical insights into CogNoTutoR's effectiveness, reinforcing its role as a resource-efficient and ethical solution within educational technology. With its foundation in sustainability and resource conservation,

CogNoTutoR offers a promising framework for advancing metacognitive skills, meeting both educational and environmental goals.

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A PREDICTIVE ANALYSIS OF STUDENT DROPOUTS IN IT HIGHER EDUCATION PROGRAMMES

U.G.N. Kumari[*]

Faculty of Information Technology, University of Moratuwa, Sri Lanka
niranjala23@yahoo.com[*]

ABSTRACT: The study primarily aims at identifying the key attributes that contribute to student dropouts in Information Communication Technology (ICT) courses offered by Higher Education Institutes, a significant issue in educational data mining. It seeks to explore the distinct factors influencing dropout rates that have been underexplored in existing literature. Data was collected from five batches of students enrolled in an Information Technology course at a government tertiary education institute in Sri Lanka. The collected data underwent pre-processing and feature selection was carried out using the Correlation-Based Feature Selection (CFS) to pinpoint subsets of attributes closely linked to dropout outcomes. Mostly used classification algorithms were evaluated based on their performance using confusion matrix metrics. Therefore, this study trains a set of classification models, namely Decision Tree, K-Nearest Neighbor, Naïve Bayes, and Rule-Based approaches that attained an accuracy of over 83.17% in defining strong associations between dropout factors and dropout status which is known as "Yes" and "No". J48 Decision Tree was the topmost algorithm for this dataset, and the predictive modeling of student profiles was done using the same. The model's performance was validated using a new dataset sourced from institutional records. The dropout prediction application was implemented using the Java WEKA API and achieved 92.61% accuracy in predicting student dropouts in ICT higher education in all educational streams. By uncovering strong relationships between dropout factors and dropout status, the study highlights key influences, with the most significant factors being perceived course quality, previous academic qualifications, previous ICT experience, Ordinary Level results, and English proficiency level in the Sri Lankan context. This model can be utilized to predictively analyze student dropouts in ICT higher education, allowing early identification of at-risk students and facilitating targeted intervention strategies.

Keywords: classification algorithms, data mining, dropouts

1. INTRODUCTION

Student academic performance is vital for educational institutions, especially in identifying at-risk students for timely interventions. In higher education, dropout rates pose a significant challenge, affecting student success and institutional reputation. Although existing studies have examined dropout predictors, a gap remains in understanding the unique factors influencing dropout rates within ICT programs. Prior research in educational data mining (EDM) has used techniques like regression, clustering, and classification to reveal academic performance patterns. However, these often generalized findings fail to capture the distinct characteristics of ICT education, which requires specific skills and learning styles. Moreover, factors such as academic background, socioeconomic status, and prior ICT experience are underexplored in dropout prediction, particularly in datasets spanning multiple years and cohorts. This study addresses these gaps by focusing on ICT programs in Sri Lanka's tertiary education, specifically through classification techniques in data mining to identify key dropout attributes. Using data from the Higher National Diploma in Information Technology at the Sri Lanka Institute of Advanced Technological Education, the research evaluates classification algorithms to determine the most effective dropout predictor. This approach tailors the predictive model to ICT students' unique profiles, moving beyond the "one-size-fits-all" method. By focusing on ICT-specific attributes, this research aims to help educational institutions mitigate dropout rates and foster a more adaptive educational environment.

1.1. Related Work

Educational predictive analysis uses data from schools and online platforms, applying data mining techniques like classification algorithms to reveal learning patterns and relationships (Lee & Chung, 2019). Educational Data Mining (EDM) employs classification and prediction to interpret student behaviour, converting large datasets into actionable insights. Known as Knowledge Discovery in Databases (KDD), DM identifies academic performance factors, with algorithms like Neural

Networks, Decision Trees, SVM, and Naïve Bayes widely used for accurate predictions(Jalota & Agrawal, 2019). Studies show that factors such as demographics, income, motivation, mental health, institutional support, and curriculum relevance affect dropout rates, highlighting the importance of multidimensional analysis in addressing dropout issues(Ortiz-Lozano et al., 2020).

1.2. Theory and Technology Use

This study combines feature selection, classification techniques, and cross-validation to optimize predictive accuracy in data analysis and machine learning. Using Correlation-Based Feature Selection (CFS) and the WEKA platform, the research leverages both supervised and unsupervised learning to handle data complexity effectively. The WEKA tool, implemented in Java, supports a wide range of machine learning algorithms, providing a strong foundation for model development and analysis. This integrated approach ensures a robust framework for extracting meaningful insights from data, balancing theoretical principles with advanced technological tools(Kemper et al., 2020).

2. METHODOLOGY

This study investigates the effectiveness of classification algorithms in data mining to predict student dropouts in Information Technology (IT) higher education. It aims to address four critical questions: identifying dropout factors through correlation-based feature selection, determining the most relevant factors, selecting the best classification algorithm, and evaluating the accuracy of prediction tools like the Decision Tree Algorithm. The goal is to develop a reliable predictive model for dropout rates in IT programs, ensuring that the evaluation of dropout data is timely, dependable, and adaptable. The research utilizes a training dataset containing instances with a target class attribute, essential for constructing a stable model. The accuracy of the model is validated against a separate test dataset. The study anticipates first identifying key factors contributing to student dropouts through a literature review, followed by using correlation-based feature selection to highlight the most significant factors(Yağcı, 2022). Various algorithms will be tested on collected datasets to determine the most accurate classification technique for constructing the predictive analysis model, and the performance will be measured.

The dataset comprises theoretical and empirical factors impacting student performance, including socio-demographic indicators (age, geographical location, parents' education, and income), educational factors (performance in O/L and A/L examinations, prior ICT education, and entrance exam scores), as well as institutional, psychological, and social integration factors. Data preprocessing is crucial, involving evaluation of data quality and integrity. Missing values are addressed through mean and mode imputation for continuous and categorical variables, respectively, to maintain dataset integrity. Continuous variables like English scores and income are normalized to a common scale (0 to 1), preventing larger range variables from skewing results, particularly in distance-based algorithms like K-Nearest Neighbor. Categorical variables are encoded using one-hot encoding to ensure compatibility with machine learning algorithms, avoiding biased interpretations that can arise from inherent ordering in categorical data. Outliers in continuous variables are managed using z-score analysis, capping values beyond three standard deviations to preserve the majority of the dataset while reducing noise.

After preprocessing, the dataset is prepared for data mining techniques. The feature selection process identifies the most useful inputs for analysis by eliminating irrelevant attributes. Based on previous studies, several classifiers are tested, including Decision Tree (J48), K-Nearest Neighbor (Lazy-IBK), Naïve Bayes, and Rule-Based ZeroR. Test datasets with record sizes of 500 to 1000 are created to assess changes in accuracy for each algorithm. Classification accuracy is evaluated using the test data, and once satisfactory, classification rules can be applied to new data. The findings reveal that

the J48 Decision Tree and K-Nearest Neighbor classifiers are the top performers, with the J48 Decision Tree achieving 100% accuracy in predicting student dropouts. Consequently, it is selected as the preferred model for application. To achieve high accuracy and mitigate over-fitting, the study employs cross-validation, pruning techniques for the Decision Tree classifier, and adjustments to reduce noise sensitivity and enhance generalization in the K-Nearest Neighbor classifier(Matzavela & Alepis, 2021). The predictive application is developed using the Java WEKA API, effectively uncovering hidden patterns in the training dataset. These derived prediction patterns are integrated into a functional application designed to predict student success, showcasing the study's contribution to improving dropout prediction in IT higher education. Overall, this research demonstrates the potential of classification algorithms to identify at-risk students, facilitating targeted interventions to enhance student retention and success in tertiary level IT courses.

3. RESULTS AND DISCUSSION

This study generated the following four classification models: Decision Tree-J48, Naïve Bayes, K-Nearest Neighbor-Lazy-IBK, and Rule-Based-ZeroR. Testing was then done on a dataset with a number of 2000 instances divided into several subsets with 500, 600, 700, 800, 900, and 1000 instances to test changes in accuracy as the instances increase for each of the selected algorithms: Naïve Bayes, Lazy-IBK, J48, and ZeroR. The study compares four classifiers for predicting dropouts in ICT higher education, focusing on accuracy, precision, and recall. Both the Decision Tree (J48) and K-Nearest (lazy-IBK) classifiers achieved perfect scores (100%) in accuracy, precision, and recall, outperforming Naïve Bayes and ZeroR, the latter scoring lowest. Key factors influencing dropout include income, demographics, institutional support, psychological aspects (like self-efficacy and motivation), and social integration (peer support and cultural fit). J48 stands out as the most effective model due to its user-friendly, interpretable structure, making it ideal for accurately assessing dropout risks (Burgos et al., 2018). The Confusion Matrix in Table 1 illustrates the performance of each classifier, detailing the numbers of true positives, false positives, true negatives, and false negatives encountered during evaluation.

Table 1. Confusion Matrix for Model Evaluation

Classifier	True Positives (TP)	False Positives (FP)	True Negatives (TN)	False Negatives (FN)
J48	100	0	0	0
lazy-IBK	100	0	0	0
Naïve Bayes	91	8	27	5
ZeroR	0	0	83	17

4. CONCLUSION

This study effectively uses the Decision Tree method to predict student dropouts in ICT higher education, achieving 100% accuracy in identifying key relationships between dropout factors and prediction outcomes. By training classification techniques like Decision Tree, K-Nearest Neighbor, Naïve Bayes, and Rule-Based models, the research demonstrates over 83% accuracy, with J48 and K-Nearest Neighbor performing best. Critical dropout factors include academic performance, prior ICT experience, socio-economic status, motivation, and institutional characteristics. A proposed predictive tool based on these findings could help educators assess dropout risks at admission, enabling targeted interventions. However, the study's reliance on a single institutional dataset may limit its generalizability to other ICT contexts. Future improvements could include refining predictors with advanced feature selection and applying ensemble methods, such as Random Forests, to enhance model resilience. Further research into association and rule mining may uncover additional patterns, broadening dropout intervention strategies for diverse educational settings.

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THE IMPACT OF GAME-BASED LEARNING ON VOCABULARY DEVELOPMENT AMONG ESL UNDERGRADUATES

R. Raleesha[*]
General Sir John Kotelawala Defence University, Sri Lanka
radmiraleesharr@gmail.com[*]

ABSTRACT: In language learning, using games to teach vocabulary makes studying both fun and effective, creating an enjoyable learning experience for students. Thus, this research aims at investigating the impact of game-based learning on the development of vocabulary among undergraduates, specifically focusing on first-year law undergraduates at a university in Sri Lanka. The primary objective is to determine whether incorporating games into vocabulary teaching leads to improvements in language proficiency. The study employed a variety of instruments to assess the impact, including the APTIS test, a comprehensive vocabulary test, a pretest, a posttest, and interactive activities such as the Word-Wall activity and the Slap the Board game. The selection of these instruments provided a thorough evaluation of the students' vocabulary acquisition and retention through diverse assessment methods. The rationale for selecting first-year law undergraduates as participants stems from the limited research available on the impact of game-based learning in developing vocabulary among undergraduates within the Sri Lankan context. The participants first completed a pretest to establish their baseline vocabulary proficiency, followed by a series of game-based interventions, and finally, a posttest to measure the effectiveness of game-based learning. The results of the empirical study indicated a significant difference between the pretest and posttest data, indicating that incorporating games into the vocabulary teaching process positively impacts vocabulary development. The findings underscore the potential of game-based learning as an effective pedagogical tool for enhancing vocabulary acquisition in the ELT context. This paper contributes to the existing body of knowledge by shedding light on an underexplored area of game-based learning in the Sri Lankan context and advocates for the integration of such innovative methodologies to develop vocabulary among undergraduates.

Keywords: game-based learning, vocabulary development

1. INTRODUCTION

English Language Teaching (ELT) has undergone a significant transformation as educators adopt innovative methods to address diverse learner needs (Syafrizal & Haerudin, 2018). Game-based learning has gained prominence as an engaging alternative to traditional teaching approaches, combining entertainment with education to enhance language acquisition. Recognizing vocabulary as a cornerstone of effective communication (Decarrico, 2001), educators are increasingly leveraging the interactive nature of games to foster a deeper understanding and application of new words (Kolb, 1984). This approach transforms classrooms into dynamic, learner-centered environments that address challenges such as sustaining student interest and accommodating varied learning styles.

This research examines the impact of game-based learning on vocabulary development, specifically among first-year undergraduates in Sri Lanka. By comparing pre-test and post-test results, the study explores the effectiveness of two types of games: one implemented in classroom groups and another that incorporates technology through mobile devices or laptops. While previous studies have investigated game-based vocabulary improvement, research focusing on its application in Sri Lanka's ELT context remains limited. This study contributes to the understanding of how games enhance vocabulary retention and sustain learner interest, enabling educators to make informed decisions about integrating these strategies into their teaching practices.

2. METHODOLOGY

The research aimed to explore potential differences between in-class games and digital-based activities in teaching vocabulary to first-year undergraduates. Using a quantitative research design, the study sought to understand the influence of incorporating games in the vocabulary teaching process.

2.1 Participants

The study involved 48 first-year law undergraduates from a Sri Lankan university, aged between 18–25, with an intermediate level of English proficiency. The participants, both male and female, were equally divided into three groups: two experimental groups and one control group, with 16 participants in each group. Group allocation was based on their APTIS test marks. A convenience sampling strategy was employed, selecting participants who were readily available for the research.

2.2 Procedure

The research aimed to examine the effectiveness of game-based learning in enhancing vocabulary within ELT. First, the APTIS test was administered to identify 48 intermediate-level learners. A vocabulary test based on Paul Nation's framework established that participants fell within the 5k–7k range. A customized test consisting of 20 questions assessed both receptive and productive skills. Two game-based activities were implemented: a digital Word Wall activity and an in-class Slap the Board game.

During the Word Wall activity, participants matched words with meanings using mobile phones or computers, receiving immediate feedback on their responses. During the Slap the Board game, participants worked in teams to identify target words on a whiteboard based on meanings provided by the instructor. The game was repeated three times to reinforce learning. The control group completed only pre-tests and post-tests without additional activities. Data collection involved gathering pre-test and post-test scores from all groups. IBM SPSS Statistics was used for analysis to identify differences in vocabulary improvement.

2.3 Data Analysis

Data analysis was conducted to determine the impact of game-based learning on vocabulary development. Pre-test and post-test scores were analyzed using IBM SPSS Statistics. The paired samples t-test and its non-parametric counterpart, the Wilcoxon Signed Rank Test, were utilized to evaluate the statistical significance of vocabulary improvement among the experimental and control groups.

3. RESULTS

The research instrument's reliability was assessed using Cronbach's Alpha, which yielded a value of 0.699 (rounded to 0.7) (Table 1). This meets the threshold for reliability (≥ 0.7) recommended by Mishra et al. (2019) and Tavakol and Dennick (2011), confirming the instrument's reliability.

Table 1. Reliability Test

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.699	.650	6

The Kolmogorov-Smirnov and Shapiro-Wilk tests revealed significant deviations from normality across most variables ($p < 0.05$) (Table 2). Consequently, nonparametric tests were applied for further analysis.

The Kruskal-Wallis H test was conducted on GainR and GainP (Table 03) variables with three groups (df = 2). The test statistics, 17.373 and 22.136, accompanied by extremely low p-values (.000), indicate significant differences between groups. This nonparametric test assesses whether there are statistically significant differences in medians among groups. The results reject the null hypothesis of equal medians, providing robust evidence that GainR and GainP vary significantly across the specified groups, as suggested by the Kruskal-Wallis test.

Table 2. Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
PreR	.277	48	.000	.869	48	.000
GainR	.155	48	.005	.946	48	.028
PreP	.223	48	.000	.867	48	.000
PostR	.206	48	.000	.827	48	.000
PostP	.180	48	.000	.912	48	.002
GainP	.154	48	.006	.964	48	.153

Note: a = Lilliefors Significance Correction

Table 3. Comparative Analysis of Learning Gains in Receptive and Productive Skills Across 'Word wall activity' and 'slap the board game'

Test Statistics[a,b]

	GainR	GainP
Kruskal-Wallis H	17.373	22.136
df	2	2
Asymp. Sig.	.000	.000

Note: a = Kruskal Wallis Test; b = Grouping Variable: Group

4. DISCUSSION

The study investigated differences in pre-test and post-test scores focusing on receptive and productive skills, using Word Wall activities and the Slap the Board game. Data analysis revealed that all groups showed improvement, but the experimental groups outperformed the control group, indicating the effectiveness of game-based methods over traditional teaching approaches. Specifically, significant improvements were observed in receptive and productive skills for both experimental groups using the Word Wall activity and the Slap the Board game (Tables 03). While the control group showed some progress in receptive skills, no significant change was found in productive skills. This highlights that game-based learning is particularly effective in enhancing productive vocabulary skills.

The Word Wall activity demonstrated a substantial positive impact on vocabulary learning, as participants showed significant advancements in both receptive and productive skills, supported by the reliability test results (Cronbach's Alpha). Similarly, the Slap the Board game proved effective, with Wilcoxon Signed Rank Test results indicating significant improvements in both skill areas. Comparative analysis using the Kruskal-Wallis H test revealed that the learning gains from the two game types varied, emphasizing the importance of aligning game selection with instructional goals and student preferences. These findings underscore that incorporating game-based methods in ELT classrooms significantly enhances vocabulary acquisition compared to traditional methods.

Despite these positive results, there were challenges such as participant availability and initial unfamiliarity with the Slap the Board game. Engagement improved in later rounds, demonstrating the importance of adapting activities to learners' proficiency levels. Recommendations include selecting games based on learners' background, proficiency, and preferences—adult learners, for

instance, may prefer individual games. The study highlights the need for flexibility, continuous refinement of methods, and tailored game choices to maximize engagement and effectiveness in vocabulary learning.

5. CONCLUSION

This study provides evidence that incorporating games like Word Wall and Slap the Board into vocabulary instruction can be more effective than traditional methods, particularly for improving productive vocabulary skills. While traditional methods may lead to some receptive vocabulary gains, digital games appear to offer a significant advantage for both receptive and productive skills development.

In conclusion, the integration of games into ELT represents a dynamic and effective strategy for teaching vocabulary. The engagement, motivation, contextual learning, repetition, collaborative opportunities, and the incorporation of intrinsic and extrinsic rewards collectively contribute to a comprehensive approach that enhances vocabulary acquisition. As educators strive to create engaging and effective language learning experiences, games emerge as a valuable tool that not only makes the process enjoyable but also maximizes the potential for long-term retention and application of vocabulary in real-world contexts.

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THE IMPACT OF SOCIAL ANXIETY, LEARNING ORIENTATION, AND LEARNER AUTONOMY ON SECOND LANGUAGE LEARNER ENGAGEMENT AT TERTIARY LEVEL: A SUSTAINABLE APPROACH TO ESL EDUCATION

M. Samarakoon[1] and U. E. Liyanarathna[2]

[1]Sri Lanka Technology Campus, Sri Lanka, [2]Institute of Technology, University of Moratuwa, Sri Lanka

Mudrika1026@gmail.com[1], udaraliy@gmail.com[2]

ABSTRACT: The issue of ESL learner engagement at tertiary level in Sri Lanka has been a subject of concern for many years. Factors such as social anxiety, learning orientation, and learner autonomy have been identified as critical components affecting engagement, which, in turn, influence students' learning abilities and academic achievement. While the relationship between social anxiety and academic outcomes has been extensively studied, the specific ways in which social anxiety, learner autonomy, and learning orientation impact learner engagement in the Sri Lankan context remain unclear. Notably, many graduates from state universities in Sri Lanka, particularly those from the Faculties of Arts, Social Sciences, and Humanities, face significant challenges due to insufficient proficiency in English. This study seeks to investigate the effects of social anxiety, learner autonomy, and learning orientation on learner engagement at tertiary level. A quantitative research approach was adopted, utilizing Structural Equation Modeling (SEM) to analyze a sample of 204 participants from the Faculty of Humanities and Social Sciences at a Sri Lankan state university. Data collection was carried out through a questionnaire, which incorporated an adapted version of the Social Phobia Inventory to measure social anxiety, while exploratory factor analysis was employed to assess learner engagement. The gathered data were subsequently analyzed using SEM. Contrary to previous studies, the findings of this research reveal that social anxiety does not have a significant impact on ESL learners' engagement in their tertiary-level language classrooms. However, both learning orientation and learner autonomy were found to positively influence learner engagement. Therefore, the study concludes that for a sustainable approach to ESL education, the roles of social anxiety, learner autonomy, and learning orientation are critical, although no direct interrelationship between these factors was identified.

Keywords: English as a Second Language (ESL), learner engagement, System Equation Modeling (SEM), tertiary level, sustainable education

1. INTRODUCTION

The goal of this research is to identify the impact of social anxiety, learning orientation, and learner autonomy on learner engagement in tertiary-level ESL classrooms in Sri Lanka. This study is also significant as the study tries to address a critical gap in the literature on ESL learning in Sri Lanka, focusing on motivational and psychological aspects influencing students' engagement. The acquired knowledge can be used to develop teaching practices and policy decisions that will support the sustainable development of ESL education programs in Sri Lanka at tertiary level.

To evaluate and identify the impact of social anxiety, learner autonomy, and learning orientation on learner engagement of ESL learners at tertiary-level, the study identifies two objectives through the goal of the study.

Objective 01: To identify the learner engagement in tertiary-level classrooms in Sri Lanka.

Objective 02: To identify the individual correlation between social anxiety, learner autonomy, and learning orientation on learner engagement in tertiary-level ESL classrooms.

To fulfill the two objectives, the study designed one research question (RQ);

RQ 01: To what extent do social anxiety, learner autonomy, and learning orientation impact ESL learner's engagement in the target language?

To understand the question, the study designed three hypotheses (H01);

H01: Second language learners' social anxiety negatively affects their learner engagement.

H02: Learner autonomy has a positive impact on learner engagement.

H03: Undergraduate learning orientation has a positive effect on ESL learner engagement.

2. METHODOLOGY

This study used a quantitative research design and analyzed the data using structural equation modeling (SEM). It is based on pre-existing notions regarding second-language learner involvement and was created through a thorough examination of scholarly literature. The study used a primary data collection strategy in which participants' answers to a Google questionnaire were directly retrieved. To obtain the necessary information for statistical data collection, respondents self-enumerated in response to a Google questionnaire used for primary data collection.

First-year undergraduates following the compulsory English courses offered by the Faculty of Humanities and Social Sciences were taken as the sample of this study. The developed Google questionnaires were distributed amongst the undergraduates through their respective English lecturers. The participants were informed and elucidated regarding the nature of the research before completing the Google survey and 204 responses were obtained.

Data were gathered using a questionnaire as the statistical method developed by the researcher, adopting the Social Phobia Inventory (SPIN) (Connor et al., 2000), the Academic Self-Regulation Questionnaire (SRQ) (Miller & Brown, 1991), the Learning Orientation Questionnaire (LCQ) (Biggs et al., 2001), and finally, Exploratory Factor Analysis (EFA) (Fabrigar L.R. & Wegener, D.T., 2012).

The Dynamic Systems Theory (DST) was used as a theory to incorporate and evaluate each variable's interaction more critically. The hypothesis has proven to be useful in the analysis of peer contagion and their learner engagement in the ESL classroom, antisocial development and its influence when it comes to the ESL performance, and the development of ESL related dynamics. Additionally, DST has acted as a guide for the execution of multilevel treatments, including successful school transition support. Thus, the researcher attempts to explore other variable aspects that might affect learner engagement while identifying relationships between social anxiety, learning orientation, and learner autonomy in second language learning engagement by including DST in this study.

Further, multivariate analysis is a statistical technique that allows for the simultaneous observation of two or more variables. There was a clear identification of one variable as the dependent (learner engagement (LE)) and the other as the independent (social anxiety (SA), learning orientation (LO), and learner autonomy (LA)). This analytical technique can be applied to analyze the relationship between the variables and ascertain their interactions and respective impacts using a comprehensive advanced examination. Nemours techniques are used in the multivariate analysis, even though structural equation modeling, or SEM, was the primary analytical method used in this study. SEM is the result of combining factor analysis and multiple regression analysis. Because of this, SPSS and AMOS were both used in the data analysis process.

3. RESULTS AND DISCUSSION

The reliability and validity of the data were examined before conducting the SEM analysis. Thus, Cronbach alpha value was utilized to test the reliability analysis that should be greater than 0.7. Further, the KMO value was used to identify the validity of the data that needs to be higher than 0.6 (Table 01).

Table 1. Reliability and Validity

Variable	No. of Items	Reliability	Validity
LA	7	0.725	0.685
LO	7	0.871	0.872
SA	6	0.873	0.865
LE	7	0.747	0.827

After successfully passing the reliability and validity test, the correlation of the measurement model was tested, and the results indicated a weak (Negligible) positive correlation between LA and LO. The P values between the LA, SA and LA and LO are significantly higher than the intended 0.05 P value making the variables statistically significant, the remaining two correlations between LA, SA, and SA, & LO indicated a weak negative correlation. Hence, it can be concluded that the correlations among the independent variables are not strong (Table 02).

Table 2. Discriminant Validity of the Measurement Model

Interrelated Variables			Correlation	P
LA	<- ->	SA	-0.107	0.174
LA	<- ->	LO	0.052	0.521
SA	<- ->	LO	-0.265	0.002

To acknowledge the direct impact of learner autonomy, learner orientation, and social anxiety on the general degree of language learner engagement, a structural model was created. Learner autonomy, social anxiety, and learner orientation were the three endogenous primary latent components that made up the Suggested structural model. The exogenous construct was language learner engagement. Table 3 indicates the direct effects of each variable on the dependent variable which is learner engagement.

Table 3. Direct Effects of Independent Variables

Path	Path Coefficients	Standardized Path Coefficients	Standard Error	CR	P - Value	Decision
LA->LE	-0.007	-0.006	0.073	-0.092	0.927	Not Supportive
LO-> LE	0.775	0.623	0.111	6.981	0.000	Supportive
SA-> LE	0.054	0.074	0.052	1.034	0.301	Not Supportive

As per the results (Table 3), the path from LA to LE indicates a negligible negative relationship as evidenced by the very low path ecoefficiency. The P value of 0.927 far exceeds the significance threshold of 0.05, indicating the relationship is not statistically significant. Contradictory, the path between LO and LE is robust with a positive significance of 0.775. The Standard path coefficient of 0.623 further underscores the strength of this as the P value of 0.000 is well below the threshold point of intended 0.05, which makes it statistically significant. The path of SA to LE reveals a positive (minor) coefficient of 0.054, which is small yet statistically insignificant as shown by the P value of 0.301.

The link between learner autonomy and engagement, in contrast to earlier research, is based on the fact that motivated students are more likely to assume accountability for their own education, which in turn promotes autonomy (Reeve, 2013). In contrast to most prior research, the current study indicates that the relationship between involvement and autonomy might be context-dependent and that cultural attitudes regarding the subject can play a significant mediating role (Dörnyei, 2001). The findings of Fredrics, Blumenfeld, and Paris (2004) that behavioral involvement may not always result in increased autonomy are further supported by these findings.

Furthermore, the significant positive relation between Learning orientation and learner engagement proves that learners with high learning orientation are driven by an internal desire to master skills and understand concepts, rather than simply achieving grades or rewards (Dwecks, 1986) encouraging students to invest time and effort, despite obstacles. When students see the relevance of their studies to real-world applications, their intrinsic motivation and engagement often increase (Reeve, 2006) by the mastery goals, emotional, and cognitive resilience- positively influence students' engagement across behavioral, emotional, and cognitive dimensions (Dweck, 1986).

Interestingly, the results indicate no significant impact of social anxiety on L2 learner engagement. This contradicts most previous literature, which has consistently highlighted the negative consequences of learner engagement (Hwang et al., 2020). While earlier research, such as Young (1991), often emphasized the adverse effects of social anxiety on second language acquisition, the current study found no substantial evidence to support this claim. Respondents generally disagreed with the notion that they were fearful of making mistakes in their L2 when interacting with fluent speakers, further countering the claims of the previous findings.

4. CONCLUSION

In conclusion, the study emphasizes the critical role learning orientation has established as a predictor of engagement across learner engagement domains. Learning-oriented students who prioritize mastery over performance, display higher engagement in academic tasks. Fostering a learning orientation can create a positive cycle of engagement and achievement by promoting self-regulation, mastery-oriented tasks, and autonomy-supportive teaching strategies, educators can enhance engagement levels and encourage students to take ownership of their learning (Reeve, 2006). The literature aligns closely with the results of the study showcasing that learning-oriented students are consistently more engaged and resilient.

Moreover, the less impactive findings between learner autonomy and learner engagement suggest the need for more targeted, autonomy-supportive instructional strategies that may go beyond merely promoting engagement. The need to emphasize reflective practices, goal setting, and offering students opportunities to make decisions could be more effective as stated by Littlewood in 1999. Notably, the results challenge the prevailing assumption that social anxiety negatively affects L2 learner engagement. Contrary to previous research, such as Hwang et al. (2020), which highlights the detrimental impact of social anxiety on learner participation, the current study found no significant evidence to support this. Respondents largely refuted the idea that they were apprehensive about making mistakes in their L2 interactions with fluent speakers, further reinforcing these findings. Social anxiety can significantly hinder learner engagement, especially in language learning contexts where communication and interaction are key. By addressing social anxiety, educators can create more inclusive environments, ensuring that all students have equal opportunities to succeed while helping educators to build resilient learning communities where students feel supported and are more likely to engage with their peers, fostering a collaborative and sustainable learning environment.

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INTERGRATING SOHRAI AND KHOVAR TRIBAL ART MOTIFS FROM JHARIKHAND, INDIA INTO SRI LANKAN BATIK HOME FURNISHINGS

N. A. N. L. Jayathilake[*]

Institute of Technology University of Moratuwa, Sri Lanka

lakshaniitum@gmail.com[*]

ABSTRCT: Sri Lanka is one of the major countries that practice the batik technique. Therefore, it is essential to support traditional batik designers by providing them with innovative, value-added designs and motifs. The study focused on introducing *Sohrai* and *Khovar* tribal art motifs from Jharkhand in India into Sri Lankan home furnishing products. During the Covid-19 pandemic, SriLankan government took steps to develop and revive traditional batik art. Thus, this study aimed to revive both Indian tribal art and the Sri Lankan traditional batik industry while introducing value-added products that meet modern consumer needs and preserve lesser-known Sohrai and Khovar tribal art. The experimental study involved conducting a comprehensive literature survey to explore Sohrai and Khovar motifs followed by a survey conducted for selected 25 batik designers, artists, and manufacturers from Sri Lanka to gain comprehensive insights into the designs. Due to limitations during the pandemic, the survey was conducted online.25 experienced batik designers were selected with the support of the National Craft Council. Based on the findings, 25 *Sohrai* and *Khovar* tribal art motifs were selected for designing different layouts suitable for Sri Lankan batik home furnishings such as wall hangings, cushion covers, tablecloths, bed runners, and bed sheets. The main colours utilized were black, white, yellow ochre, and brownish red. The study will have a significant impact as it will contribute to the global exchange of cultural heritage while supporting SriLankan batik designers and preserving lesser-known tribal arts.

Keywords: home furnishings, *Khovar* tribal art, Sri Lankan batik industry, *Sohrai*

1. INTRODUCTION

Batik, an ancient textile craft originating over two millennia ago, involves applying designs on fabric by masking areas to prevent dye absorption (Sreenivasam, 1989). Today batik textile manufacturing in Sri Lanka is deep-rooted into the local culture and many local artists have embraced it as one of our own, developing unique wax resist and dying techniques to create batik designs that are unique to Sri Lankan batik artists (Sri Lankan Export Development Board, 2015). Wickramasinghe (2020) has explained the steps taken by the government to develop and preserve the traditional batik art. A proposal was tabled to encourage state sector employees to embrace Sri Lanka's Batik and local textile culture with a mandatory wearing of batik or handloom apparels once a week, as a step to promote local apparels.

A separate ministry was formed in Sri Lanka during the Covid pandemic to revive the dying industry and to encourage improvements in the batik industry (Hussainmiya 2020). As per the Sri Lankan Export Development Board (2015), the growing interest of tourists in batik was sufficient to keep the art alive as a cottage industry in the nooks and corners of Sri Lanka. It is the government backing provided through the National Crafts Council, Sri Lanka Handicrafts Board, Institute of Textiles & Apparel (SLITA) and Sri Lanka Export Development Board which encouraged a generation of batik artists to create and experiment with new form and techniques in batik, giving a local flavour to a global tradition. To address the above requirement, the researcher aimed to introduce innovative and culturally rich batik designs to Sri Lankan batik industry. As a result, this study focuses to explore the integration of Indian tribal motifs into Sri Lankan batik designs.

India is home to over 2500 tribes and their diverse cultures are vividly reflected through crafts such as W*arli, Tanjore, Madhubani, Saura, Bhill, Gond, Pattachitra, Kalamazethu, Sohrai,* and *Khovar* paintings (Xavier ,2012). Among these, *Sohrai* and *Khova*r art from the *Birhor* tribes of Jharkhand involves decorating walls with nature-inspired motifs and is less known outside the region (Cheng, 2002). This approach seeks to create innovative batik designs and to support Sri Lankan batik designers while preserving lesser-known traditional tribal art. Besides, the study opens opportunities for global exchange as it introduces the culturally rich heritage of tribal art into the Sri Lankan batik industry through home furnishing products such as wall hangings, cushion covers, tablecloths, bed

runners, and bed sheets. The primary objectives of this study are to study about *Sohrai* and *Khovar* tribal motifs and to develop new designs with more aesthetic appeal and adapt these designs in creating distinctive batik home furnishing products to support Sri Lankan batik artists and manufactures.

2. METHODOLOGY

As this study was conducted during the COVID pandemic in 2020, due to travel restrictions, a comprehensive literature was conducted referring to books, websites, and interviews on *Sohrai* and *khovar* tribal art forms and colours. Then, general information on Sri Lankan batik home furnishing products was gathered through designers and manufacturers.25 designers, artists, and manufacturers with over five years' experience were selected with the help of the National Craft Council and a survey was administered to gather information on product selection, motif sizes, and design preferences. Additionally, an online form was employed for the same sample to identify and categorize the products that best suited as home furnishing products focusing on motif selection from *Sohrai* and *Khovar*. During the product design development phase, 25 designs (5 per category) were created, and those designs were digitally edited to standard sizes available sizes. From these, 5 final designs (one per category) were selected based on respondents' preferences, with the highest-scoring designs chosen for further development.

3. RESULTS

Initially, the motifs and colours of the *Sohrai* and *Khovar* tribal wall paintings were deeply observed which are suitable for the design process. The theme of those paintings includes wild animals in their natural habitats and domestic animal forms such as cow, bull, fowl, pigeon and various types of other animals dwelling together in forest and other nature inspired designs painted on mud walls. The figures in these paintings are drawn with bold outlines (see Figure 1). Even though these motifs are associated with specific meanings, their aesthetics and suitability for batik technique was only considered. Based on the traditional colours used in *Sohrai* and *Khovar* tribal art, the researcher selected a colour palette consisting of black, white, yellow ochre, brownish red to develop new designs.

Fig. 1. Sohrai and Khovar Tribal Paintings on Walls

The researcher identified a total of 25 motifs from wall paintings, which were broadly categorized into three styles: floral, birds, and animals. Specifically, this included 8 floral motifs, 9 bird motifs, and 8 animal motifs for screening. (see Fig. 2)
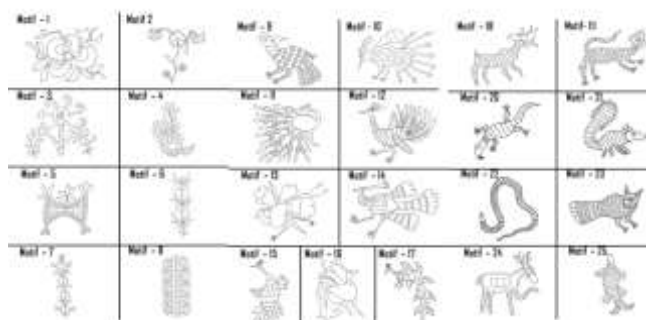
Fig. 2. Selected 25 motifs identified for screening

The responses of 25 participants on their preference of motifs were obtained for the selection of final motifs. Preference choices were given to the designers and manufacturers about the sizes and the appearance of motifs. According to this fact, motif sizes were classified into extra-large, large, medium, small. As per the results of the survey it was noted that the Sri Lankan designers and manufacturers preferred to incorporate a mix of motif sizes and mix of bold and subtle figures for product designing. The motif sizes and appearance of motifs as recorded by the respondents are shown in Fig. 3.

Out of the 25 collected motifs, 10 motifs for design development were selected (3 florals, 4 birds, and 3 animal motifs) based on their aesthetic appeal. The distribution of motif category and their preferences are shown in Fig. 4. Most preferred 10 motifs by the designers (Motifs no. 1, 4, 8.9, 13, 15, 16, 20,23 and 25) along with a description of each layout are shown in Table 1.
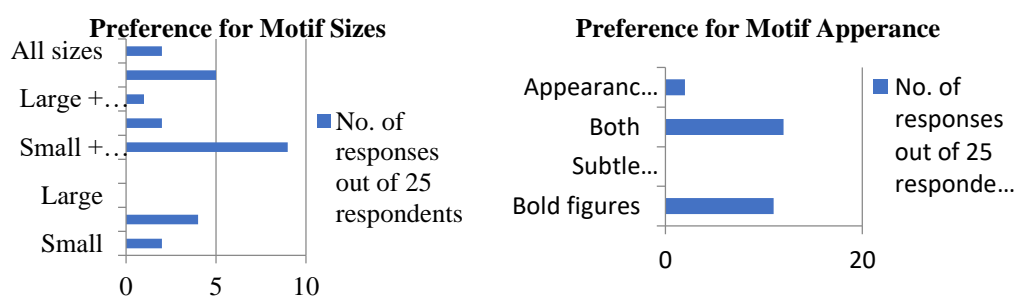
Fig. 3. Preferences for Motif Sizes and Appearance
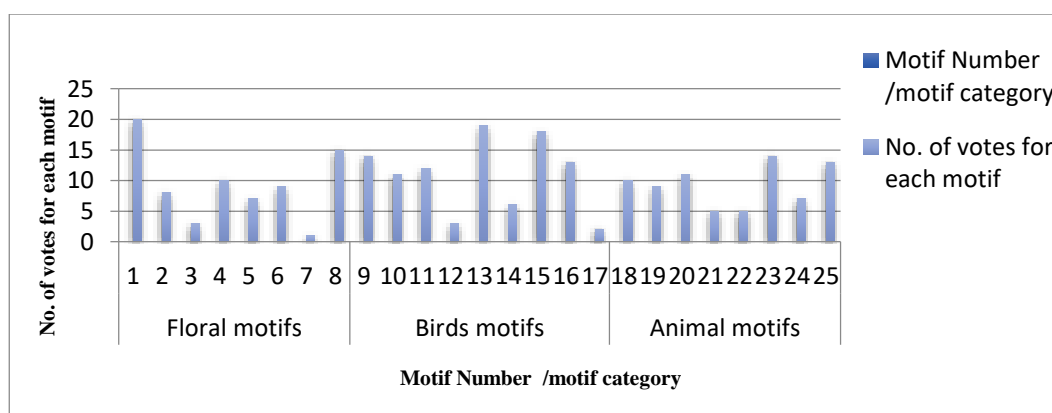
Fig. 4. Preference for Each Motif Category

Table 1. Details of Selected Motifs

Motif No.	Design details	Motif No.	Design details
Motif no. 1	Wide petals with leaves	Motif no. 15	A bird like a peacock
Motif No.4	A big flower with multiple small sections	Motif No.16	A bird like the Sri Lankan peacock
Motif No. 8	Extended design with many repeats	Motif No.20	Animal design with four legs and scales
Motif No. 9	A bird motif with an action	Motif No.23	A bird like an owl with so many feather-like structures
Motif No.13	A bird motif with huge feathers with many designs	Motif No.25	A fish with many scale designs

Further, the selection of home furnishing products was done after analysing the results of the initial survey. The researcher analysed and categorized the products that have a higher demand as home furnishing products in terms of acceptance. Among the respondents, 60% opted for wall hangings, 56% of the respondents for bed cover and 44% for tablecloth. 24% and 8% respondents voted for cushion cover and bed runner respectively. Table runner, lamp shade and tablemats were found to have a lesser demand. After evaluation of the above results according to the percentage value of responses, first five products in higher demand including wall hanging, bed cover, tablecloth, cushion cover, and bed runner were chosen as final product items for further development.

Based on the data collected from the survey on product category and motifs, a total of 25 design layouts were prepared with 5 designs (one design for each category) for product development. The evaluation was conducted by the same 25 respondents who selected their preferred designs. The designs with the highest number of votes in each category were then finalized for product development as layouts1, 8, 11,16 and 25 with a score of 32%, 52%, 32% ,32% and 44% respectively.

Article 1 (Wall hanging) - The selected design layout (Layout: 1) which got the highest responses had bird and floral motifs designed in only two colours black and yellow ochre placed within one-inch black colour frame.

Article 2 (Bed cover) - The design layout (Layout: 8) was arranged with two extra-large sized bird motifs and designed in mainly black, white and yellow ochre colours.

Article 3 (Tablecloth) - The layout (Layout: 11) was selected for tablecloth design as it was the most preferred by the respondents. The background of this selected layout was kept white with a multi-coloured floral border on all four sides. The centre portion of the layout had bird motifs in yellow ochre outline placed in black background.

Article 4 (Cushion cover) - In this layout (Layout: 16) stylized floral motif inspired from *Sohrai* and *Khovar* art was arranged diagonally in white, black, and yellow ochre colours.

Article 5 (Bed runner) - The background of this layout (Layout: 25) was yellow ochre. Medium sized motifs of two birds facing each other were placed in the middle of the design layout and two flowers were kept at the opposite corners of the bed runner in black colour.

Finally, the selected designs were incorporated into home furnishing products using batik techniques (see Fig. 5).

Wall hanger

Table cloth

Cushion cover

Bed runner

Bed cover

Fig. 5. Final products

4. CONCLUSION

Batik industry in Sri Lanka has developed into a large form of textile business exclusive to the country. Batiks in Sri Lanka incorporate many motifs and colours, some traditional, others highly contemporary and stylized. Thus, there is a growing interest for batik products and the Sri Lankan government is providing ample support to increase the demand and encourage the artists to create and experiment with new forms giving a local flavour to a global market requirement. Today, consumers always look for exclusive products with novelty. Hence, adapting Indian motifs to Sri Lankan home furnishing designs have given a proper direction to how this need can be satisfied with the creation of value-added products without changing unique traditional features. It is recommended to continue this study to get new insights about the product acceptability and cost evaluation for both local and export market. Also, it can be recommended that the developed designs may be used in various other products such as saris, shawls, sarong, and curtains.

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CULTIVATING GRATITUDE IN AN ACADEMIC SETTING THROUGH A VIRTUAL PLATFORM: A DIGITAL GRATITUDE SHOW

A. D. Weerakoon[*]

Institute of Technology University of Moratuwa, Sri Lanka

amalidhanu22@gmail.com[*]

ABSTRACT: A growing number of academics, educators, and thought leaders suggest that gratitude is one of seven key character strengths alongside grit, zest, self-control, optimism, social intelligence and curiosity that predict students' success both in academic settings and in the corporate world. This research project aimed at enhancing the attitude of gratitude among a group of polymer technology students in their final academic semester. To achieve this, a Digital Gratitude Show was conducted as the culminating event of an online mock interview program designed to prepare students for real-world professional interviews. According to the qualitative analysis conducted using descriptive statistics of panelists' feedback based on a satisfaction scale, the panelists felt highly appreciated for their dedication in helping students succeed in a realistic interview setting. As defined by the Concise Oxford Dictionary gratitude is "the quality of being thankful; readiness to show appreciation and to return kindness." In line with this definition, the students expressed sincere and profound gratitude to the panelists for their invaluable guidance during online mock interviews which played a crucial role in their preparation for actual interviews. The Digital Gratitude Show can be regarded as an innovative, student-centered pedagogical approach that effectively fosters an attitude of gratitude in students as they transition into the corporate world.

Keywords: digital gratitude show, gratitude, graduate attributes, online mock interviews

1. INTRODUCTION

The development of digital tools for online education began well before the COVID-19 pandemic; however, widespread adoption occurred only after the onset of the pandemic. In response to COVID-19, educational institutions worldwide were compelled to shift to online and hybrid models, leveraging alternative teaching methods. Even after strict lockdowns were lifted, many universities have continued to utilize these tools due to their convenience, efficiency, and time-saving benefits (Aleksandr, 2022). The evolving economic landscape has placed a premium on higher education's role in producing graduates equipped with both knowledge and skills that align with workforce demands. Today, graduates are assessed not only on their subject matter expertise but also on the breadth of their skills which significantly enhances their employability. Among the most highly sought-after attributes by employers are soft skills—such as interpersonal abilities, work ethic, self-direction, and communication proficiency (Cimatti, 2016). These qualities are highly valued, as they reflect an individual's capacity to thrive in both personal and professional settings.

1.1. Gratitude

An increasing number of academics, educators, and thought leaders recognize gratitude as one of seven essential character strengths alongside grit, zest, self-discipline, optimism, social intelligence and curiosity proven to drive students' success, not only in academic settings but also in the corporate world (Wilson, 2016).

The Concise Oxford Dictionary defines gratitude as "the quality of being thankful; a readiness to show appreciation and to return kindness." When equated with the act of giving thanks, gratitude takes on a universal significance, understood and valued across all cultures. Its meaning transcends a fleeting thought or emotion—it calls for intentional expression. This expression often manifests as "gratitude to someone" or "gratitude for something or someone." True gratitude permeates one's entire being, requiring the engagement of intellect, will, and emotions to transform simple acknowledgment into genuine thanksgiving (Alex, 2008).

Gratitude serves as a fundamental cohesive force within society (Howells, 2004). It is often referred to as the "moral memory of mankind," as when we feel gratitude toward someone or for something, we internalize it as a memory, compelling us to act upon it when given the chance. Dispositional

gratitude is linked to a more positive, appreciative outlook on life, fostering a constructive bias in how we interpret social interactions (Emmons and Crumpler, 2000).

Gratitude can be expressed toward peers, objects, or acts of kindness that elicit positive emotions in the recipient (Tsang, 2006). Individuals vary in their propensity to feel gratitude (McCullough et al., 2003), and this variation can be distinguished by four key facets: intensity, frequency, span, and density. These dimensions refer to the strength and regularity of one's gratitude, the breadth of situations that evoke it, and the depth of appreciation experienced across different contexts.

1.2. Importance of Expressing Gratitude

Gratitude, often regarded as the quintessential positive psychological trait, fosters a life orientation that actively seeks and acknowledges the good in the world. Its emotional and psychological benefits are closely linked to enhanced physical vitality. Gratitude is an appreciation for continuous experiences of life. Experience is defined as something one undergoes and gratitude in this context refers to the appreciation elicited by events or occurrences that an individual encounters or feels (McCullough et al., 2003). Gratitude is described as a 'constant experience of life' because it must be cultivated and felt daily to appreciate positive events and avoid being overwhelmed by negative ones. Individuals who do not consistently practice gratitude in their daily interactions may find it challenging to develop a genuine sense of appreciation. This difficulty can also extend to expressing gratitude in social interactions.

The learning process operates within a triad of interconnected domains: cognitive, affective, and psychomotor. To achieve optimal learning outcomes, it is essential to integrate these three domains seamlessly. However, the affective domain, often sidelined, represents a crucial aspect of education. This domain encompasses the emotional experiences of learners, including their attitudes, beliefs, impressions, and sentiments, as well as behavioral attributes such as gratitude, empathy, interest, and responsibility (Noor et al., 2020). By prioritizing the affective domain, educators can enhance student engagement and foster a more holistic approach to learning (McCullough et al., 2004). The benefits of cultivating an enhanced attitude of gratitude extend beyond improving mood and well-being. Gratitude serves as an indicator of effective functioning and aids in the achievement of concrete life goals.

1.3. Aims and Objectives of the Research

During the COVID-19 pandemic, many leading employers in the polymer industry transitioned to conducting online interviews for internship recruitment—a practice they continue to favour for its convenience and time-saving benefits. This research project aimed to equip final-semester Polymer Technology students with a heightened sense of gratitude by organizing a Digital Gratitude Show as the culminating event of an online mock interview program.

2. METHODOLOGY

2.1. Conducting Online Mock Interviews for Semester IV Polymer Technology Students

The initial step of the project was to identify suitable panelists for the online mock interview sessions. Through a combination of emails and phone conversations, six leading companies in the polymer industry were selected to participate. A total of 10 distinct interview panels were formed, and the online mock interviews were conducted over six sessions, following a structured 10-step process. Each panel consisted of a minimum of three Polymer Technology experts, a human resources manager, and the researcher. To enhance the experience, a customized flyer was created for each session with the support of the students. All 41 Semester IV Polymer Technology students participated in the program. Each student was interviewed for 30 minutes, covering various aspects including technical knowledge and fundamental interview questions. After each interview, constructive feedback was provided to help students improve. Additionally, recordings of all

individual mock interviews were uploaded to Moodle, allowing students to review their performance and further prepare for success in real-world interviews.

2.2. Conducting a Digital Gratitude Show as the Culminating Event of an Online Mock Interview Program

As the culminating event of an online mock interview program, a Digital Gratitude Show was organized facilitating all Semester IV Polymer Technology students to express their appreciation to the panelists for their voluntary commitment in making the program a success. An invitation flyer with an eye-catching design and the event agenda, and customized Zoom background were created and shared with all panel members via email. In addition to the panelists, the Director of ITUM, academic staff, and all students from the Polymer Technology discipline were invited to participate in this event.

2.3. Collecting Feedback from Panelists

Feedback from the panelists was collected to recognize their invaluable guidance during the mock interview sessions, which will aid students in succeeding in real interview contexts. This feedback was gathered through a self-administered, close-ended questionnaire based on a satisfaction scale (1 = Very Low; 5 = Very High). It covered 14 appreciation aspects of the Digital Gratitude Show: invitation flyer , Zoom background for the digital gratitude show, welcome speech by a student, introductory speech to the digital gratitude show by the chief organizer (researcher), group photo for the ITUM Newsletter, speech by the Director/ITUM, speech by the Head of the Division of Polymer and Chemical Engineering Technology, entertainment item by the students, students' perspectives on mock interviews, speech by a panelist, speech by the Head of Industrial Training, Career Guidance, and Post-Diploma Center of ITUM, speech delivered by a student to express gratitude , vote of thanks speech by a student, and appreciation letters. Feedback obtained for the above items was analyzed to qualitatively evaluate whether students successfully expressed gratitude and enhanced their attitude of gratitude.

3. RESULTS AND DISCUSSION

Feedback from all 20 panelists was analyzed qualitatively using descriptive statistics as shown in Table 1. According to the descriptive statistics on appreciation aspects of the Digital Gratitude Show, all panelists reported feeling highly appreciated for invaluable guidance they provided during the mock interview sessions, which will aid students in succeeding at actual interviews. For elements such as the invitation flyer, students' perspectives on mock interviews, a heartfelt message of gratitude from a student and the appreciation letters, all panelists expressed a very high level of satisfaction. Additionally, over 80% of the panelists felt very highly valued during various segments of the Digital Gratitude Show, including the use of the Zoom background, the welcome speech by a student, the event introduction by the chief organizer, and the speech by the Director of ITUM. These gestures effectively highlighted students' gratitude for the guidance received. For aspects such as the speech by the Head of the Division of Polymer and Chemical Engineering Technology, the group photo for the ITUM Newsletter, the entertainment item by the students, the speech by a panelist, and the speech by the Head of the Industrial Training, Career Guidance, and Post Diploma Center of ITUM, approximately 50% of the panelists felt highly appreciated, while the other 50% felt very highly appreciated by the students. For the vote of thanks delivered by a student, more than 75% of the panelists felt deeply appreciated for their volunteer dedication in supporting students' success in real interview scenarios.

Table 1. Panelists' feedback: Descriptive statistics and frequencies (N=20)

Aspects of appreciation in Digital Gratitude Show	Contribution Frequency and Percentage				
	Satisfaction scale)1 =Very Low; 5 =Very High(				
	Very Low	**Low**	**Moderate**	**High**	**Very High**
Invitation flyer for the digital gratitude show	00	00	00	00	20 (100%)
Zoom Background for the digital gratitude show	00	00	00	04 (20%)	16 (80%)
Welcome speech by a student	00	00	00	03 (15%)	17 (85%)
Introduction to the digital gratitude show by the chief organizer (researcher)	00	00	00	02 (10%)	18 (90%)
Group photo for the ITUM Newsletter	00	00	00	10 50%)	10 (50%)
Speech by the Director/ITUM	00	00	00	02 (10%)	18 (90%)
Speech by the Head of the Division of Polymer and Chemical Engineering Technology	00	00	00	11 (55%)	09 (45%)
Entertainment item by the students	00	00	00	10 (50%)	10 (50%)
Students 'perspectives on mock interviews	00	00	00	00	20 (100%)
Speech by a panelist	00	00	00	10 (50%)	10 (50%)
Speech by the Head of the Industrial training, Career Guidance and Post Diploma Center of ITUM	00	00		10 (50%)	10 (50%)
Heartfelt Honourable Gratitude by a student	00	00	00	00	20 (100%)
Vote of thanks by a student	00	00	00	05 (25%)	15 (75%)
Appreciation letters	00	00	00	00	20 (100%)

Notably, no panelists reported feeling a very low, low, or moderate level of satisfaction for any of the appreciation aspects in the Digital Gratitude Show. Overall, the results reveal that students expressed sincere gratitude to all panelists for their commitment to helping them prepare for real-world interviews.

4. CONCLUSION

Gratitude, a valuable attitude within the affective domain, plays a critical role in both personal and interpersonal development. A Digital Gratitude Show serves as a transformative platform, uniquely positioned to instill a lasting attitude of gratitude in an academic setting. Through this virtual experience, a culture of appreciation and mutual respect flourishes, enriching the educational journey. By embracing this heightened sense of gratitude, students are not only empowered to navigate the complexities of an ever-evolving world but are also inspired to lead with resilience, confidence, and purpose—laying a strong foundation for both personal and professional success.

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CODE-SWITCHING AS A PEDAGOGICAL TOOL: A CASE STUDY IN A TECHNOLOGICAL INSTITUTION

H. G. P. Maheshika[*]

Institute of Technology University of Moratuwa, Sri Lanka

piyumimaheshikagamage@gmail.com [*]

ABSTRACT: Code-switching, switching between two or more languages, plays a significant role in language classrooms. This case study investigates its role within an English language classroom in a Sri Lankan government higher educational institution specializing in engineering technology. It focuses on the impact of code-switching on student comprehension, participation, and classroom dynamics referring to interaction, communication flow and engagement between students and teachers during lessons. In order to explore how code-switching functions in this context, a semi-structured interview with an English language teaching practitioner was conducted. The analysis draws on established sociolinguistic theories and emphasizes code-switching as a pedagogical tool that promotes inclusivity by bridging linguistic and cultural gaps in language classrooms. Findings reveal that code-switching facilitates better comprehension of complex academic content, encourages greater student participation, and positively influences classroom dynamics by enhancing engagement and interaction. In addition to that, it contributes to the sustainability of education by recognizing and incorporating students' linguistic identities into the teaching-learning process. However, in order to ensure effective prolonged language acquisition, it is crucial to maintain a balance between the first language use and the development of target language proficiency. By promoting an inclusive and culturally responsive language learning environment, this study underscores the potential of code-switching to support ethical dimensions of educational sustainability. The integration of these approaches highlights the necessity for innovative teaching methods that accommodate linguistic diversity, in alignment with broader goals of sustainability in education. The study advances current discussions on how to create equitable, linguistically sensitive classrooms that empower students from diverse linguistic backgrounds while fostering effective English language learning. It also suggests how these findings may apply beyond engineering education to broader educational contexts.

Keywords: code-switching, English Language Teaching, pedagogy, sociolinguistics, sustainability in education

1. INTRODUCTION

The global upsurge of multilingual education reflects the increasing requirement to accommodate the needs of students from diverse linguistic backgrounds in formal educational settings, particularly in English language teaching (ELT). In Sri Lanka, where the English language is commonly used as the language in higher education, language barriers might hinder students' comprehension of complex academic content, specifically in specialized fields such as engineering. Code-switching; alternating or switching between languages functions as a feasible solution to these challenges. It enables students to draw on their first languages to facilitate comprehension in English language learning (Gumperz, 1982; Myers-Scotton, 1993).

Code-switching functions as an effective pedagogical tool that promotes inclusivity and cognitive development. This is accomplished by overcoming disparities and bridging the gaps in language proficiency in ELT. The aim of this study is to examine the role of code-switching in a higher education institute of engineering in Sri Lanka, where the English language is used as the medium of instruction. However, the students frequently switch to Sinhala or Tamil when confronted with complex academic concepts making code-switching a common practice to aid understanding. The main objective of this study is to evaluate how code-switching fosters comprehension and participation and classroom dynamics—defined as interaction, communication flow, and engagement between students and teachers in a multilingual educational context. Additionally, the study addresses ethical and cultural aspects of educational sustainability by investigating how code-switching promotes equity and inclusivity in classroom settings in ELT (Baynham, 2018; Li, 2018).

2. METHODOLOGY

This study employed a qualitative methodology. A semi-structured interview was conducted with an experienced ELT practitioner from a government higher education institute of engineering. The practitioner, with over five years of experience in multilingual educational settings, was selected for their comprehensive understanding of the role of code-switching in language teaching. The interview was designed to collect data on the role of code-switching in classroom interactions. Attention was given to causes, frequency and the impact of code-switching on students' comprehension and engagement in the classroom.

The interview questions were designed to elicit in-depth responses on several key topics, including the factors that trigger code-switching, the frequency of its occurrence, and its impact on students' comprehension and participation within the classroom. Additionally, the questions explored the influence of code-switching on classroom dynamics, focusing on how it aids in communication flow and interaction between students and teachers and the pedagogical benefits and limitations of employing code-switching as a teaching method and strategies for effectively managing code-switching to foster language acquisition.

Two key sociolinguistics frameworks; Gumperz's Interactional Sociolinguistics and Myers-Scotton's Markedness Model were incorporated in order to analyze the data. Gumperz' (1982) theory posits code-switching serves as a contextualization cue, facilitating students in managing complex discourse. Moreover, Myers-Scotton (1993) claims that code-switching functions as a tool for negotiating social identity and group membership in multilingual contexts. Albirini (2011) further asserts that code-switching plays an important role in managing sociocultural identities in educational settings, particularly in ELT.

3. RESULTS AND DISCUSSION

3.1 Triggers for Code-Switching

The interview data uncovered several key factors that trigger code-switching in the classroom context. The most common trigger was the complexity of the academic content, notably in technical subjects, where specialized terminology is often difficult to comprehend in English. The data revealed that the students often resorted to their first language to clarify complex concepts with their peers. Moreover, students frequently switched to their first language in order to better articulate their thoughts during conversations that involve emotionally sensitive or culturally specific topics. These findings support and align with Gumperz's Interactional Sociolinguistics, which proposes that code-switching assists in managing complex discourse by signaling shifts in topics (Gumperz, 1982; Baynham, 2018). Albirini (2011) also highlights that code-switching enables students to negotiate their social and cultural identities more effectively in educational contexts.

3.2 Frequency of Code-Switching

The interview data disclosed that code-switching frequently occurred, especially during interactive activities such as group tasks. According to the ELT practitioner, students usually initiate discussions in English but would switch to their first language; Sinhala or Tamil upon encountering difficulties. This consistent switching between languages facilitated collaboration allowing students to explain complex ideas or share culturally relevant examples by using their first languages. This finding supports Myers-Scotton's Markedness Model, which posits code-switching functions as a strategic tool for maintaining group cohesion and negotiating social identities in multilingual contexts, especially those focused on English language learning (Myers-Scotton, 1993).

3.3 Impact on Comprehension and Participation and Classroom Dynamics

Classroom dynamics, in this context, refers to how students interact, communicate, and engage during lessons. Code-switching allows for smoother communication flow, encourages peer collaboration, and fosters a more inclusive atmosphere, particularly beneficial for students less

confident in the target language. Students with lower proficiency in the target language benefit from the ability to switch to their first language, as it allows them to clarify complex academic concepts. This further promotes engagement in classroom discussions. However, the practitioner asserts that frequent use of code-switching may hinder prolonged language acquisition, as it reduces students' exposure to the target language. This finding underscores the potential drawbacks of relying on code-switching and the importance of a balanced approach that facilitates comprehension while promoting sustained language development.

3.4 Code-Switching and Educational Sustainability

By fostering inclusivity and acknowledging linguistic and cultural identities of the students, code-switching facilitates sustainability in education. Allowing students to switch between languages helps educators foster inclusive learning environments that support linguistic diversity and ensure equal access to education for all students. This approach aligns with the ethical dimensions of educational sustainability, by preventing the marginalization of students from diverse linguistic backgrounds (Li, 2018). In addition, code-switching promotes culturally responsive pedagogy by acknowledging students' first languages as assets rather than hindrances to academic success in ELT.

4. CONCLUSION

This study illustrates that code-switching functions as an important pedagogical tool in multilingual educational settings, especially where students encounter significant language barriers in English language learning. By allowing students the flexibility to incorporate their first language as required, the ELT practitioners can enhance comprehension, promote active participation and create more inclusive learning environments. Nonetheless, this study underscores the importance of regulating code-switching to reduce over-reliance on first languages, which may hinder prolonged language acquisition. The findings of this study suggest that code-switching contributes significantly to educational sustainability, particularly by embracing linguistic diversity. The incorporation of innovative pedagogical approaches that integrate code-switching will be vital, as educational institutions strive to accommodate diverse linguistic needs of students. This will ensure that all students, regardless of their linguistic backgrounds, have equal access to quality education. Future research should explore the prolonged effects of code-switching on language acquisition and academic performance.

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A COMPARISON OF NUTRITIONAL KNOWLEDGE AND DIETARY HABITS OF UNDER 15 AND 17 BADMINTON PLAYERS OF SELECTED SCHOOLS IN SOUTHERN AND WESTERN PROVINCE

J. A. S. D. Bandara[1*] and W. E. Iroshani[2]
[1,2]Institute of Technology University of Moratuwa, Sri Lanka
shalinid@itum.mrt.ac.lk[1*], iroshanie@itum.mrt.ac.lk[2]

ABSTRACT: This study investigated nutritional knowledge and dietary habits among under-15 and under-17 badminton players in Sri Lanka's Southern and Western provinces, examining the relationship between nutritional understanding and eating practices, while also exploring gender-based differences. The research involved 40 badminton players who completed a comprehensive questionnaire, approved by Institutional Review Board (IRB) of California University of Pennsylvania covering demographics, dietary habits, and nutritional knowledge. Results revealed that parents (45%) and schools (30%) were the primary sources of nutritional information, with coaches playing a minimal role (12.5%). Statistical analysis using SPSS showed a weak negative correlation ($r = -0.040$, $p > 0.05$) between dietary habits and nutritional knowledge, indicating no significant relationship. Western Province players demonstrated higher levels of good nutritional knowledge (85%) compared to Southern Province athletes (70%). Similarly, Western Province athletes exhibited better dietary habits, with 90% showing good practices, while 60% of Southern Province players maintained fair dietary habits. Gender analysis revealed that dietary patterns were similar between males and females, though male athletes showed slightly higher nutritional knowledge (85%) compared to females (70%). The study recommends enhancing parental and school involvement in nutrition education, encouraging greater coach participation in dietary guidance. Future research should consider using larger sample sizes and examine socioeconomic factors to better understand the influences on young athletes' dietary practices, as the current findings indicate a disconnect between nutritional knowledge and practical application.

Keywords: athletes, badminton, habits, knowledge, nutrition

1. INTRODUCTION

Badminton is a fast-paced racket sport requiring a unique blend of technical skill, sport-specific fitness, and tactical awareness. It can be played in singles or doubles, but at competitive levels, athletes need high aerobic endurance, strength, and agility. The sport's intensity, combined with short intervals between multiple matches and prolonged durations, highlights the need for proper nutrition to sustain peak performance. Nutrition directly impacts energy levels, recovery, and overall health, all of which are critical for athletes (Grandjean, 1997). Research shows that a well-balanced diet, particularly one rich in carbohydrates and essential nutrients optimizes athletic performance, especially in sports with sustained energy demands (Van Erp-Baartl, 2007; Spronk, 2014). Conversely, poor dietary habits, like high-fat or low-nutrient food intake, can impair performance by increasing fatigue and limiting movement (Hale, 2013). This need for proper nutrition is even greater for young athletes managing both growth and athletic development.

Understanding nutritional practices is essential for athletes and those who guide them coaches, trainers, and guardians as their dietary guidance can significantly impact young athletes' health and performance (Rockwell, Richedson, & Thye, 2003). Knowledge of nutrition has a direct effect on dietary practices, yet studies suggest that inadequate understanding may lead to suboptimal eating habits that impede performance and recovery (Susan, 2011). For youth athletes especially, forming good dietary habits is critical, as they are not only striving to perform but are also establishing lifelong nutrition practices.

Moreover, gender-specific nutritional needs and knowledge levels may affect athletes' dietary choices, which can influence their performance (Azizi, 2011; Rezaee & Azizi, 1992). Recognizing these gender-based differences is essential to develop tailored nutritional support that meets the distinct needs of both male and female athletes. Additionally, cultural and regional factors play a role in shaping athletes' access to nutritional information and their capacity to practice healthy dietary habits.

This study compares the nutritional knowledge and dietary habits of under-15 and under-17 badminton players from selected schools in Sri Lanka's Southern and Western provinces. It examines how dietary habits relate to nutritional knowledge, explores gender-based differences, and identifies primary sources of nutritional information. The research also assesses regional variations between the two provinces.

Findings from this study will determine whether young athletes' nutritional understanding translates into practices that support athletic performance. The results aim to guide targeted nutrition education interventions, addressing any gaps between knowledge and practice. Insights gained will help design age-appropriate, region-specific, and gender-sensitive nutrition programs, benefiting coaches, schools, and parents in supporting young athletes' dietary needs and athletic development.

2. METHODOLOGY

This research was designed using a cross-sectional survey method. The sample consisted of 40 players, under 15 and 17, selected from schools in the Southern and Western provinces. Data was collected through a standard questionnaire approved by the Institutional Review Board (IRB) of California University of Pennsylvania. The questionnaire, administered to badminton players from the selected schools, was divided into three sections: demographics, dietary habits, and nutritional knowledge.

The demographic section required students to answer questions about gender, age, and grade in School, sport, height and weight. The dietary habits section, consisting of 18 questions, inquired into how often they consumed specific food items. This section included questions about the frequency of consumption of foods from each portion of the food pyramid, as well as consumption of beverages, and vitamin and mineral supplements, and practices such as dieting and skipping meals. The nutritional knowledge section aimed to assess each athlete's level of knowledge about nutrition and included 29 questions where students indicated the extent to which they agreed with the given statements which were designed to gather data on.

The data analyzed from SPSS software, employing both descriptive statistics and the Pearson correlation coefficient to examine relationships between variables. Descriptive statistics provide a summary of the data, including measures with relevant percentages and frequencies. Graphical representations, including diagrams, charts, and graphs, are used to visually present the data, making it easier to identify patterns and trends. The results are comprehensively presented using these methods, ensuring a clear and detailed interpretation of the data.

3. RESULTS AND DISCUSSION

Analysis was started by obtaining the descriptive statistics of the sources from which badminton players obtain nutritional knowledge, as summarized in Table 1.

Table 1. Sources of Nutritional Information

Information source	Frequency	Percentages (%)
Coach	5	10.42
News Paper	1	2.08
TV	1	2.08
Parents	18	37.5
School	12	25.0
Nutritional course	8	16.67
Other	3	6.25

According to Table 1, most players relied on their parents (37.5%) and school (25.0%) for nutrition guidance. Only 10.42% of players sought information from their athletic coach. Additionally, 6.25%

of players turned to other sources, such as doctors or nutritionists, for nutritional advice. Both television and newspapers accounted for only 2.08% each, indicating that players are not heavily relying on these media for nutritional knowledge.

According to Fig. 1, when comparing sources of knowledge of Southern and Western province players, Southern province players gather more nutrition knowledge (50%) from parents than Western province players (40%). However, it is evident that western province players (35%) gather more knowledge related to nutrition from school than southern province players (25%). In southern province, 20% of athletes gather nutrition knowledge from coach while 5% of western province gather knowledge from coach. Although a small fraction of western province players gathers information from doctors and nutritionists, 0% of southern province players seek guidance from them.
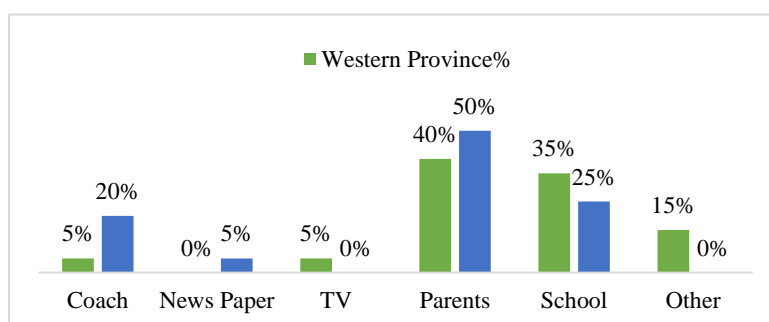

Fig. 1. Comparison of knowledge sources of player from southern and western

It is essential for players to have a solid understanding of nutritional knowledge, as this can greatly influence their habits and overall nutrition. In order to gather information on students' nutritional knowledge and dietary habits several questions were designed, and a mark was awarded for each answer. Scores were calculated according to their responses and classified into the following categories: Excellent (85-100%), Good (70-84%), Fair (55-69%), and Poor (54% or lower). The nutritional knowledge scores of the players from each provinces were compared, and the results are presented in Fig. 2.
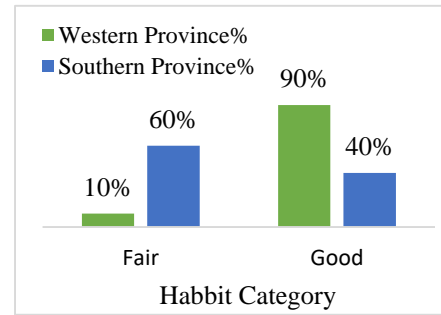
When comparing the nutritional knowledge score between provinces, many students demonstrated a good level of understanding. Specifically, 85% of players from the Western Province achieved a 'Good' level of nutritional knowledge, compared to 70% of players from the Southern Province. Additionally, 30% of players from the Western Province and 15% from the Southern Province were classified as having 'Fair' nutritional knowledge. Overall, the majority of players from both provinces possess an adequate level of nutritional knowledge. Notably, no players from either province reached 'Excellent' or 'Poor' knowledge levels. Province-wise dietary habit scores were compared, and the results are illustrated in Fig. 3.

Considering southern province players, 60% of them have got fair dietary habits and 40% show good dietary habits. No players from either province reported having excellent or poor dietary habits. Then the relationship between nutritional knowledge and dietary habits were statistically analyses using Pearson's correlation. Results are shown in Table 2. Table 2 shows the relationship between nutritional knowledge and dietary habits of players. Pearson Correlation value was -0.040 indicating a weak negative correlation between dietary habits and nutritional knowledge. However, the p value indicates that there is no significant relationship between nutritional knowledge and dietary habits, as p-value >0.05. Table 3 and 4 below illustrate gender based dietary habits and nutritional knowledge among players.
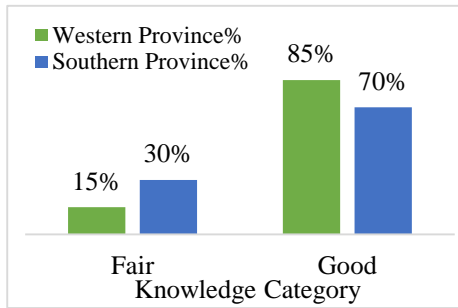
Fig. 2. Comparison of nutrition knowledge between the provinces

Fig. 3. Comparison of Dietary habits

Table 2. Pearson Correlation between Total Dietary Habits and Nutritional Knowledge Scores

Variable		Dietary Habits	Nutritional Knowledge
Dietary Habits	Pearson Correlation (r)	1	-.040
	Sig. (2-tailed) (p-value)		.804

Table 3. Difference of Dietary Habits according to Gender

Habit category	Gender		Total
	Female	**Male**	
Fair (% within gender)	6 (30%)	8 (40%)	14 (35%)
Good (% within gender)	14 (70%)	12 (60%)	26 (65%)
Total (% within gender)	20 (100%)	20 (100%)	40 (100%)

As depicted in Table 3, irrespective of gender, both male and female players exhibit good dietary habits, with 65% of players (70% of females and 60% of males) falling into the 'Good' category. This suggests that a majority of players, regardless of gender, maintain favorable dietary practices.

Table 4. Gender -wise Difference in Nutrition Knowledge

Knowledge category	Gender		Total
	Female	**Male**	
Fair (% within Gender)	6 (30.0%)	3 (15.0%)	9 (22.5%)
Good (% within Gender)	14 (70.0%)	17 (85.0%)	31 (77.5%)
Total (% within Gender)	20 (100.0%)	20 (100.0%)	40 (100.0%)

Table 4 shows that the majority of players exhibit good nutritional knowledge, with 70.0% of females and 85.0% of males demonstrating this level. Males have a higher percentage of good nutritional knowledge (85.0%) compared to females (70.0%), while a greater proportion of females (30.0%) have only fair knowledge.

4. CONCLUSION

This study explored the nutritional knowledge and dietary habits of under-15 and under-17 badminton players in the Southern and Western provinces of Sri Lanka. Findings showed that although players generally have good nutritional knowledge, especially among Western Province athletes (85% vs. 70% in the Southern Province), this knowledge has not translated into healthy dietary habits. Parental (37.5%) and school influences (25%) were the primary sources of nutritional information, with minimal input from Television and newspapers (2.08%).

Notably, Western Province athletes exhibited better dietary habits (90% in the "good" category) compared to those in the Southern Province, where most players fell into the "fair" category (60%). Gender differences were minimal regarding dietary habits, though male athletes displayed slightly better nutritional knowledge (85%) than female athletes (70%). However, no statistically significant correlation was found between nutritional knowledge and dietary habits (Pearson correlation -0.040, $p > 0.05$), indicating that factors beyond knowledge such as accessibility, socio-economic status, and personal preferences may play a role in shaping athletes' dietary practices.

The study recommends several key actions to enhance the nutritional knowledge and dietary habits of young athletes. First, parental and school involvement is crucial, as athletes primarily obtain nutritional information from these sources. Providing nutritional education to both parents and teachers through workshops or seminars would ensure that athletes receive consistent and accurate dietary advice. Second, coaches should be encouraged to play a more active role in guiding their athletes' dietary habits. Training sessions on sports nutrition for coaches could empower them to offer effective nutritional guidance.

Finally, further research is needed to expand the sample size and explore the influence of socio-economic factors, training schedules, and psychological aspects on athletes' dietary habits and nutritional knowledge. This comprehensive approach will contribute to better health and performance outcomes for young athletes.

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CORPUS LINGUISTICS FOR ESL MATERIAL DESIGNING: A QUALITATIVE STUDY BASED ON ANTCONC SOFTWARE

L. W. D. B. Pabasarani[*]
Institute of Technology University of Moratuwa, Sri Lanka
[*]bhagyap@itum.mrt.ac.lk

bhagyap@itum.mrt.ac.lk

ABSTRACT: Corpus Linguistics in the context of English as a Second Language (ESL) is high in demand as an approach that guides ESL practitioners in making informed decisions about language teaching. This discipline of Corpus Linguistics can be efficiently incorporated into material designing and teaching methodology, paving the way for both feasible and quality teaching and learning processes. The tool used for corpus analysis in this research is AntConc software. This research aims to unravel how the data derived from AntConc software can be used to make materials that reflect the real-life language use. The analysis derived from studying and analyzing a corpus is indeed an effective guide in the context of English Language Teaching (ELT). The text analysis performed by this software proves that the frequent patterns of language it identifies are a valuable resource for creating materials that accurately represent real-life language use.

Keywords: corpus linguistics, material designing

1. INTRODUCTION

According to Reppen (2010), a corpus is a 'large, principled collection of naturally occurring texts, (written or spoken) stored electronically'. This can be based on any actual written compilation of texts or transcribed spoken texts, collected for a particular purpose. The phrase 'naturally occurring texts' indicates the fact that the compilation must consist of authentic texts, which should indicate the real-life language use.

The next question raising worthwhile is what does it mean by Corpus Linguistics? Although it cannot be traced as a separate branch of Linguistics, it is proven to be beneficial in various other components of Linguistics, such as, Phonology, Phonetics, Morphology and Sociolinguistics. Corpus Linguistics is the research-based analysis of a given corpora which aims at decoding Corpus Linguistics properties such as Concordancing/Key Word in a Context (KWIC), Collocates, Multi-word expressions, Frequency lists, and Keyword lists. The analysis requires corpus analysis software such as AntConc or Compleat Lexical Tutor.

As Bennett (2010) points out there are two main research questions in Corpus Linguistics.

- What specific patterns are associated with lexical or grammatical features?

- How do these patterns can be differentiated within varieties and register?

Providing answers for the given questions can unravel the overarching as well as the underpinning connections between words, paving the way to understand the patterns of language.

Studies on Corpus Linguistics have long been held focusing on various concerns in the field of ESL. One such concern is about material designing and development and how the language prompted by materials in the classroom does not resonate with the language used for real life communication purposes. This is indicated by Johns (2022) stating that 'if compared to real data, textbooks do not always offer a realistic model of spoken language in terms of its forms and discourse feature.' The best way to bridge the gap between language used in the classroom and real-life language use is to use authentic materials for teaching. This is in fact one of the most crucially significant decisions that ESL practitioners should take. The aim of this paper is to incorporate the analysis of Corpus Linguistics with material designing, which promotes authentic or real-life language use. The analysis of the AntConc software can solve the matter if material designers can use the result of the analysis to develop or design materials which prompt the real-life language. The corpus analysis not only assists the ELT practitioners in making right choices in material designing but also provide chances

in cooperating authentic evidence in language teaching. In other words, the Corpus Linguistics analysis helps ELT practitioners to authenticate the language in a given context.

There are two main objectives in this research.

- To do an in-depth analysis of the feature; 'Key Word in a Context', (KWIC) by using the AntConc software specifically focusing on Conjunctions.

- To find different question types in which the analysis of the corpus can be utilized when designing materials for intermediate learners effectively.

There are many Corpus Linguistics tools such as Concordancing /KWIC, Collocates, Multi-word Expressions, Frequency Lists, and Keyword Lists. This research specifically focuses on Concordance of KWIC in order drive succinct results. In this approach, the targeted word class is Conjunctions. The focus is only targeted towards Conjunctions, since it assists in developing the materials based on Conjunctions in a more detailed manner. This choice is also made in order to maintain reliability.

2. METHODOLOGY

As the first step, seventeen articles from the magazine 'Reader's Digest' were selected. The articles were selected aiming on a set of diverse concepts, thus it included current issues, entertainment, social issues, personal experience, inspirational stories and humour. This choice serves the fact of authentic as well diverse data which must be included in a corpus. 'Reader's Digest' magazine was a preferable option for this study since it is an internationally acclaimed publication. Next, the selected articles were converted as Ms. Word documents, creating a file for each article. Then, the meta data file was created by filling the details of the text number, genre code, text title, year of publication, publisher, Author's name, gender, place of publication and the nationality. After that, the files were converted into plain text files. As the last step the Corpus Linguistic analysis was done. In order to do that, the selected corpus files were directed to the AntConc software. Even though the articles were converted into plain text files for clarity, the AntConc was able to read the Ms. Word documents in the KWIC option. Then, the analysis of KWIC was done by selecting specific words which were consisted of conjunctions and an intensive study was conducted searching the patterns of the language in right context and left context. The chosen conjunction was typed in the search query; thus, the results were shown indicating the word both in left context and right context. The target group of students aimed here are intermediate level students and to be specific, they are at upper intermediate level. According to the Common European Framework of Reference (CEFR) the students are at the level of B2. As the British Council depicts it, the 'level B2 corresponds to independent users of the language, i.e., those who have the necessary fluency to communicate without effort with native speakers.

3. RESULTS

The selected Conjunctions for this research are 'and', 'that', 'but', 'when', and 'because'. These Conjunctions were selected since they cater to the level of the learners who are intermediate and for the fact that they frequently appeared in the chosen texts.

The first key word analyzed in this research is 'and'. The most frequently appeared word in the right context of the word 'and' appears as "and the" pattern. The next pattern which appears the most in the right context is the pattern of 'and then'. As always it is used to indicate subsequent actions. At the same time the pattern of "and a + quantifier phrase" was quite prominent. The phrases noticeable were 'and a pair of', 'and a whole lot of' and 'and a few'. The pattern of 'and + Possessive Adjective' such as 'and my', 'and his' could be deciphered. Also, the pattern of "and + Subject Pronoun" was visibly deciphered too.

The second keyword analysed in this research is 'that'. When concerning the used word towards the right context, the main pattern which could be sorted out here was the pattern of 'that the'. This pattern has appeared in contexts where the writer wants to showcase a distinctive idea. Just as with the keyword of 'and' the pattern of 'that + possessive adjective' and the pattern of 'that + Subject Pronoun' could be unravelled. At the same time, the specific patterns towards the left contexts were not designed according to specific words or phrases, thus it was difficult to decode any pattern.

The third key word discussed here is 'but'. The most prominent pattern which could be decoded towards the right context was the pattern of 'but + subject pronoun', thus the patterns such as 'but I' and 'but it', appeared. At the same time the pattern of 'but + possessive pronoun' could be deciphered, provided with the example of 'but my'. Just as with the case of 'that', the specific patterns towards the left contexts were not designed according to specific words or phrases, thus it was difficult to decode any pattern.

The fourth key word in this research is 'when'. The most prominent pattern that could be deciphered in this word was 'when + Subject Pronoun'. The most frequently seen phrase here was 'when I'. At the same time in many cases the phrase 'when + Subject pronoun' was immediately followed by a verb. The next pattern which can be seen was 'when + a+ noun'.

The last word analysed in this research is 'because'. The first patten which could be deciphered in this pattern was the phrase 'because of'. As always it indicates a reason for a particular condition. The pattern of 'because + Subject Pronoun' could be found here as well like in previous key words. The only verb which appears after because in this corpus was 'because watching' indicating the pattern of using the Present Participle of the verb in case of using a verb, after the conjunction; because.

4. DISCUSSION

As Reppen (2010) points out 'knowing which words or which grammatical features are typical for a particular context of language use is a good starting point for instruction.'
Since the most common pattern in all five Conjunctions are 'Conjunction + Subject Pronoun' and 'Conjunction + Possessive Adjective', a gap filling activity can be given specifically focusing on the use of each structure under various contexts. A sample activity is given here.

Activity 1

Fill in the blanks, by selecting the correct phrase with the Conjunction.

1. She got very upset ……………. found out, she has failed her examination. (when she / that she)

2. She cries ………………… has failed the examination. (because she/ when she)

3. She promised …………………. will study well next time. (but she/ that she)

4. She studied well ……………… failed the examination. (but she/ and she)

The next significant word pattern is the use of Present Participle after the Conjunction of 'because'. Here in this context, the Present Participle is not used as a verb, but as a Gerund. This prescriptive grammar rule can be easily taught when it is represented through common situations in the day-to-day context. For this purpose, a question-and-answer activity is taken since it stimulates the authentic language use. For this activity, the responses are expected as short and crisp utterances since in an informal spoken context, short and crisp utterances are normally used.
When considering how students get to learn the use of vocabulary, as Reppen (2010) point outs Schimitt's (2004) notion about vocabulary, it indicates the importance of learning vocabulary 'in

groups or chunks of language', rather than learning them 'in isolation'. The same concern can be applied here and the best part of it is that the learners not only learn about vocabulary or the grammar aspect of it but also about the context of its use.

Activity 2

Fill in the blanks by using the correct verb form to make meaningful sentences. Read out your response to the class.

1. A – Why are you silent?

B – Because …………….. with you can cause many problems.

Sample answers: (talking / chatting)

2. A – Why do you like to study?

B – Because ………………. Makes me happy.

Answer – studying

As Hunston (2002) points out, 'corpora themselves can be exploited to produce language teaching materials, and can form the basis of new approaches to syllabus design and to methodology'.

The accuracy aspect of speaking can be promoted when the learners are instructed to speak using a few chosen structures in a controlled setting. Hence, the activity three is based on promoting the accuracy of speaking in a controlled setting. The students are expected to use the Conjunctions of, 'and', 'that', 'but', 'when', and 'because' in making accurate and meaningful sentences. The prompts to be used when speaking are given with the questions to assure an accurate outcome, which means that the students do not get a chance to be experimental with the language by taking risks. Since the chosen articles from 'Reader's Digest' are appreciable sources for extensive reading, the students can be instructed to read an article or two before doing this activity. During the while reading phase the teacher can emphasize the Conjunctions. Then, the following activity can be done as a post-reading activity.

Activity 3

Join the two phrases given in the brackets under each sentence by using the Conjunctions of 'and', 'that', 'but', 'when', and 'because'. Tell the correct sentence to the class.

1. What has happened to Mary? Can you tell me?
   She had a fall, …………………. now she is crying.
   Answer – She had a fall and now she is crying.

2. Why is she sad?
   Her boss has told her …………... she can no longer work with us.
   Answer – Her boss has told her that she can no longer work with us.

3. How was the food yesterday?
   We had a good spread ………………. many were spicy.
   Answer – We had a good spread, but many were spicy.

4. When are you going to start working on the project?
   Well, as usual …………………… it is just one day before the deadline.
   Answer – Well. As usual when it is just one day before the deadline.

5. Why are you in a good mood?

Well, it is ………………………. I am going to have a day-off tomorrow.

Answer – Well, it is because I am going to have a day-off tomorrow.

5. CONCLUSION

In conclusion, as corpus analysis helps in finding patterns common to a particular set of texts, analysing the corpora using a Corpus Linguistic software such as AntConc guides the ESL practitioners to take informed decisions about language teaching. The analysis can be utilized to design efficient materials. Besides, when the selected corpus is based on authentic materials, it becomes an added advantage since it effortlessly authenticates the language, while allowing the ESL practitioners to be more engaging and creative with material designing.

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