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Open Science

Open Science Philosophy

Open science encompasses unrestricted access to scientific research articles, access to data from public research, and collaborative research enabled by information and communication technology tools, models, and incentives. Broadening access to scientific research publications and data is at the heart of open science. The objective of open science is to make research outputs and its potential benefits available to the entire world and in the hands of as many as possible:

- Open science promotes a more accurate verification of scientific research results. Scientific inquiry and discovery can be sped up by combining the tools of science and information technologies. Open science will benefit society and researchers by providing faster, easier, and more efficient availability of research outputs.
- Open science reduces duplication in collecting, creating, transferring, and re-using scientific material.
- Open science increases productivity in an era of tight budgets.
- Open science results in great innovation potential and increased consumer choice from public research.
- Open science promotes public trust in science. Greater citizen engagement leads to active participation in scientific experiments and data collection.

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Open Society

An open society allows individuals to change their roles and to benefit from corresponding changes in status. Open science depends to a greater or lesser extent on digital technologies and innovations in structural processes by an open society. When realized, open science research and innovation can create investment opportunities for new and better products and services and therefore increase competitiveness and employment. Open science research and innovation is a key component of thematic open science priorities. Central to the open science digital infrastructure is enabling industry to benefit from digital technology and to underpin scientific advances through the development of an open society. Open science research and innovation can also contribute to society as a global actor because scientific relations can flourish even where global relations are strained. Open science has a critical role across many areas of decision making in providing evidence that helps understand the risks and benefits of different open science choices. Digital technology is making the conduct of open science and innovation more collaborative, more global, and more open to global citizens. Open society must embrace these changes and reinforce its position as the leading power for science, for new ideas, and for investing sustainably in the future.

It is apparent in open society that the way science works is fundamentally changing, and an equally significant transformation is taking place in how organizations and societies innovate. The advent of digital technology is making research and innovation more open, collaborative, and global. These exchanges are leading open society to develop open science and to set goals for research and innovation priority. Open science goals are materializing in the development of scientific research and innovation platforms and greater acceptance of scientific data generated by open science research. Open science research and innovation do not need help from open society to come up with great ideas, but the level of success ideas ultimately reach is undoubtedly influenced by regulation, financing, public support, and market access. Open society is playing a crucial role in improving all these success factors.

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Open science represents a new approach to the scientific process based on cooperative work and new ways of diffusing knowledge by using digital technologies and collaborative tools. These innovations capture a systemic change to the way science and research have been carried out for the last fifty years. Science is shifting from the standard practice of publishing research results in scientific publications after the research and reviews are completed. The shift is towards sharing and using all available knowledge at an earlier stage in the research process. Open science is to science what digital technology is to social and economic transactions: allowing end users to be producers of ideas, relations, and services and in doing so, enabling new working models, new social relationships and leading to a new *modus operandi* for science. Open science is as important and disruptive as e-commerce has been for the retail industry. Just like e-commerce, the open science research paradigm shift affects the whole business cycle of doing science and research. From the selection of research subjects to the carrying out of research, to its use and re-use, to the role of universities, and that of publishers are all dramatically changed. Just as the internet and globalization have profoundly changed the way we do business, interact socially, consume culture, and buy goods, these changes are now profoundly impacting how one does research and science.

The discussion on broadening the footprint of science and on novel ways to produce and spread knowledge gradually evolved from two global trends: Open Access and Open Source. The former refers to online, peer-reviewed scholarly outputs, which are free to read, with limited or no copyright and licensing restrictions, while open source refers to software created without any proprietary restriction and which can be accessed and freely used. Although open access became primarily associated with a particular publishing

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or scientific dissemination practice, open access already sought to induce a broader practice that includes the general re-use of all kinds of research products, not just publications or data. It is only more recently that open science has coalesced into the concept of a transformed scientific practice, shifting the focus of researchers' activity from publishing as fast as possible to sharing knowledge as early as possible. Open science is defined as the idea that scientific knowledge of all kinds should be openly shared as early as is practical in the discovery process. As a result, the way science is done in the future will look significantly different from the way it is done now. Open science is the ongoing evolution in the modus operandi of doing research and organizing science. This evolution is enabled by digital technology and is driven by both the globalization of the scientific community and increasing public demand to address the societal challenges of our times. Open science entails the ongoing transitions in the way research is performed, researchers collaborate, knowledge is shared, and science is organized.

Open science impacts the entire research cycle, from the inception of research to its publication, and on how this cycle is organized. The outer circle reflects the new interconnected nature of open science, while the inner circle shows the entire scientific process, from the conceptualization of research ideas to publishing. Each step in the scientific process is linked to ongoing changes brought about by open science, including the emergence of alternative systems to establish a scientific reputation; changes in the way quality and impact of research are evaluated; the growing use of scientific blogs; open annotation; and open access to data and publications. All institutions involved in science are affected, including research organizations, research councils, and funding bodies. The trends are irreversible, and they have already grown well beyond individual projects. These changes predominantly result from a bottom-up process driven by a growing number of researchers who increasingly employ social media in their research and initiate globally coordinated research projects while sharing results at an early stage in the research process.

Open science is encompassed in five schools of thought:

- the infrastructure school, concerned with technological architecture
- the public school, concerned with the accessibility of knowledge creation
- the measurement school, concerned with alternative impact assessment
- the democratic school, concerned with access to knowledge
- the pragmatic school, concerned with collaborative research

According to the measurement school, the reputation and evaluation of individual researchers are still mainly based on citation-based metrics. The h-index is an author-level metric that attempts to measure both the productivity and citation impact of the publications of a scientist or scholar. The impact factor is a measure reflecting the average number of citations to articles published in an academic journal and is used as a proxy for the relative importance of a journal.

Numerous criticisms have been made of citation-based metrics, primarily when used, and often misused, to assess the performance of individual researchers. These metrics:

- are often not applicable at the individual level
- do not take into account the broader social and economic function of scientific research
- are not adapted to the increased scale of research
- cannot recognize new types of work that researchers are performing

Web-based metrics for measuring research output, popularized as altmetrics, have recently received much attention: some measure the impact at the article level, others make it possible to assess the many outcomes of research in addition to the number of scientific articles and references. The current reputation and evaluation system has to adapt to the new dynamics of open science and acknowledge and incentivize

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engagement in open science. Researchers engaging in open science have growing expectations that their work, including intermediate products such as research data, will be better rewarded or taken into account in their career development. Vice-versa, the use, and reuse of open data will require appropriate codes of conduct requiring, for example, the proper acknowledgment of the original creator of the data.

These ongoing changes are progressively transforming scientific practices with innovative tools to facilitate communication, collaboration, and data analysis. Researchers that increasingly work together to create knowledge can employ online tools and create a shared space where creative conversation and collaboration can occur. As a result, the problem-solving process can be faster, and the range of problems that can be solved can be expanded. The ecosystem underpinning open science is evolving very rapidly. Social network platforms for researchers already attract millions of users and are being used to begin and validate more research projects.

Furthermore, the trends towards open access are redefining the framework conditions for science and thus have an impact on how open innovation is produced by encouraging a more dynamic circulation of knowledge. It can enable more science-based startups to emerge thanks to the exploitation of openly accessible research results. Open science, however, does not mean free science. It is essential to ensure that intellectual property is protected before making knowledge publicly available in order to subsequently attract investments that can help translate research results into innovation. If this is taken into account, fuller and broader access to scientific publications and research data can help to accelerate innovation. Investments that boost research and innovation in open science would benefit society with fewer barriers to knowledge transfer, open access to scientific research, and greater mobility of researchers. In this context, open access can help overcome the barriers that innovative organizations face in accessing the results of research funded by the public.

Open innovation

An open society is the largest producer of knowledge, but the phenomenon of open science is changing every aspect of the scientific method by becoming more open, inclusive, and interdisciplinary. Ensuring open society is at the forefront of open science means promoting open access to scientific data and publications alongside the highest standards of research integrity. There are few forces in this globe as engaging and unifying as science. The universal language of science maintains open channels of communication globally. Open society can maximize its gains through maintaining its presence at the highest level of scientific endeavor, and by promoting a competitive edge in the knowledge society of the information age. The ideas and initiatives described in this publication can stimulate anyone interested in open science research and innovation. It is designed to encourage debate and lead to new ideas on what and open society should do, should not do, or do differently.

An open society can lead to a research powerhouse; however, open society rarely succeeds in turning research into innovation and in getting research results to the global market. Open society must improve at making the most of its innovation talent, and that is where open innovation comes into play. The basic premise of open innovation is to open up the innovation process to all active players so that knowledge can circulate more freely and be transformed into products and services that create new markets while fostering a stronger culture of entrepreneurship. Open innovation is defined as the use of purposive inflows and outflows of knowledge to accelerate internal innovation. This original notion of open innovation was primarily based on transferring knowledge, expertise, and even resources from one company or research institution to another. This notion assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as they seek to improve their performance. The concept of open innovation is continually evolving and is moving from linear, bilateral transactions and collaborations

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towards dynamic, networked, multi-collaborative innovation ecosystems. This means that a specific innovation can no longer be seen as the result of predefined and isolated innovation activities but rather as the outcome of a complex co-creation process involving knowledge flows across the entire economic and social environment. This co-creation takes place in different parts of the innovation ecosystem and requires knowledge exchange and absorptive capacities from all the actors involved, whether businesses, academia, financial institutions, public authorities, or citizens.

Open innovation is a broad term, which encompasses several different nuances and approaches. Two main elements underpin the most recent conceptions of open innovation: the users are in the spotlight and invention becomes an innovation only if users become a part of the value creation process. Notions such as user innovation emphasize the role of citizens and users in the innovation processes as distributed sources of knowledge. This kind of public engagement is one of the aims of open science research and innovation. The term 'open' in these contexts has also been used as a synonym for 'user-centric'; creating a well-functioning ecosystem that allows co-creation and becomes essential for open innovation. In this ecosystem, relevant stakeholders are collaborating along and across industry and sector-specific value chains to co-create solutions for socio-economic and business challenges. One important element to keep in mind when discussing open innovation is that it cannot be defined in absolutely precise terms. It may be better to think of it as a point on a continuum where there is a range of context-dependent innovation activities at different stages, from research to development through to commercialization, and where some activities are more open than others. Open innovation is gaining momentum thanks to new large-scale trends such as digitalization and the mass participation and collaboration in innovation that it enables. The speed and scale of digitalization are accelerating and transforming the way one designs, develops, and manufactures products, the way one delivers services, and the products and services themselves. It is enabling innovative processes and new ways of doing business, introducing new cross-sector value chains and infrastructures.

Open society must ensure that it capitalizes on the benefits that these developments promise for citizens in terms of tackling societal challenges and boosting business and industry. Drawing on these trends, and with the aim of helping build an open innovation ecosystem in open society, the open society's concept of open innovation is characterized by:

- combining the power of ideas and knowledge from different actors to co-create new products and find solutions to societal needs
- creating shared economic and social value, including a citizen and user-centric approach
- capitalizing on the implications of trends such as digitalization, mass participation, and collaboration

In order to encourage the transition from linear knowledge transfer towards more dynamic knowledge circulation, experts agree that it is essential to create and support an open innovation ecosystem that facilitates the translation of knowledge into socio-economic value. In addition to the formal supply-side elements such as research skills, excellent science, funding and intellectual property management, there is also a need to concentrate on the demand side aspects of knowledge circulation, making sure that scientific work corresponds to the needs of the users and that knowledge is findable, accessible, interpretable and reusable. Open access to research results aims to make science more reliable, efficient, and responsive and is the springboard for increased innovation opportunities, e.g. by enabling more science-based startups to emerge. Prioritizing open science does not, however, automatically ensure that research results and scientific knowledge are commercialized or transformed into socio-economic value. In order for this to happen, open innovation must help to connect and exploit the results of open science and facilitate the faster translation of discoveries into societal use and economic value.

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Collaborations with global partners represent important sources of knowledge circulation. The globalization of research and innovation is not a new phenomenon, but it has intensified in the last decade, particularly in terms of collaborative research, international technology production, and worldwide mobility of researchers and innovative entrepreneurs. Global collaboration plays a significant role both in improving the competitiveness of open innovation ecosystems and in fostering new knowledge production worldwide. It ensures access to a broader set of competencies, resources, and skills wherever they are located, and it yields positive impacts in terms of scientific quality and research results. Collaboration enables global standard-setting, allows global challenges to be tackled more effectively, and facilitates participation in global value chains and new and emerging markets.

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Scholarly Research Review

The scholarly research review is a multidimensional evaluation procedure in which standard peer review models can be adapted in line with the ethos of scientific research, including accessible identities between reviewer and author, publishing review reports and enabling greater participation in the peer review process. Scholarly research review methods are employed to maintain standards of quality, improve performance, provide credibility, and determine suitability for publication. *Responsible Peer Review Procedure:* Responsible peer review ensures that scholarly research meets accepted disciplinary standards and ensures the dissemination of only relevant findings, free from bias, unwarranted claims, and unacceptable interpretations. Principles of responsible peer review:

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All submitted manuscripts are subject to the scholarly research review process, in which there are three stages of evaluation for consideration: pre-review manuscripts, chair-review presentation, and final-review manuscripts. All submitted full text papers, that may still be withstand the editorial review process, are presented in the conference proceedings. Manuscripts are tracked and all actions are logged by internal and external reviewers according to publication policy. External reviewers' editorial analysis consists of the evaluation reports of the conference session chairs and participants in addition to online internal and external reviewers' reports. Based on completion of the scholarly research review process, those manuscripts meeting the publication standards are published 10 days after the event date.

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Targeting Pleckstrin-2 for the Treatment of Myeloproliferative Neoplasms

Jing Yang, Peng Ji

Abstract— Myeloproliferative neoplasms (MPNs) are a group of bone marrow diseases with hyper-proliferation of mature blood cells. Increased risk of thrombosis is one of the leading causes of mortality and morbidity in MPNs. The acquired JAK2V167F mutation plays a central role in MPN pathology. JAK2 inhibitors have been developed to treat MPNs. Although JAK2 inhibitors can reduce spleen size and blood cell counts, significant side effects including anemia and thrombocytopenia often occur when high doses were used. In addition, JAK2 inhibitor treatment cannot reach molecular and pathologic remissions. Therefore, it is urgent to develop new treatment for MPNs.

Our previous study showed that pleckstrin-2, a protein that plays important roles in erythropoiesis, is a downstream target of the JAK2-STAT pathway. The expression of pleckstrin-2 is significantly higher in MPN patients and JAK2V167F-driven MPN mouse models than the control groups. Knockout of Pleckstrin-2 ameliorated JAK2V167F induced myeloproliferative phenotypes including erythrocytosis, neutrophilia, thrombocytosis and splenomegaly, and reverted the widespread vascular occlusions and lethality of JAK2V167F knockin mice. We found that the reduced red cell mass is the main contributor of the reversion of vascular occlusions. These findings reveal that pleckstrin-2 is a novel target to develop new strategy to treat MPNs.

Using an in silico approach, we screened over 100,000 compounds and found over 40 hits that potentially target the DEP domain of Pleckstrin-2, which was shown to be critical for its function. Through an in vitro mouse erythropoiesis system that closely mimics hyper-proliferative nature of the erythroid cells in MPNs, we identified inhibitor 17 (IN17) that showed potent inhibition of erythroblast enucleation and proliferation in a dose-dependent manner. IN17 did not inhibit pleckstrin-2 knockdown cells and a higher dose of IN17 was needed in pleckstrin-2 over-expressing cells, demonstrating its specificity on targeting pleckstrin-2. Isothermal Titration Calorimetry (ITC) assay showed that IN17 can bind to the purified GST-pleckstrin-2 but not to GST, suggesting there is a direct interaction between IN17 and pleckstrin-2. Furthermore, we found that IN17 significantly decreased pleckstrin-2 protein level without affecting its mRNA level, suggesting the binding between IN17 and pleckstrin-2 affects the stability of pleckstrin-2. Furthermore, we found IN17 significantly inhibits JAK2V167F driven erythropoiesis.

Overall, we identified an effective inhibitor of pleckstrin-2 that can be utilized for further in vivo testing of MPN mouse models.

Keywords— myeloproliferative neoplasms, JAK2, Plek2, small molecule.

Insect Pests Are Made, Not Born: A Case Study of Three Crop Pests in Their Native Habitats in the Central Valleys of Oaxaca, Mexico

Rafael F. del Castillo, Sonia Trujillo-Argueta

Abstract— Insects are among the most successful organisms on Earth, and their presence in crop fields causes significant damage, accounting for approximately 18% of global agricultural losses. Chemical insecticides remain widely used for pest control due to their effectiveness. However, the increasing resistance of insects, coupled with health risks and environmental pollution of soils and watersheds, highlights the urgent need for alternative solutions. In the face of climate change, pollution mitigation, and growing food demands, a paradigm shift in agroecosystem management strategies is imperative. Studying the natural habitats where insect plagues originate offers valuable insights for designing sustainable pest control strategies. The natural and semi-natural ecosystems of the Central Valleys of Oaxaca, Mexico—dominated by dry forests and scrublands—harbor insect species that are significant crop pests in other regions. For example, The cicada *Quesada gigas* (Homoptera), known for causing severe damage to commercial plantations such as *Schizolobium amazonicum* (parica), citrus, and coffee, commonly inhabits native trees like the guaje (*Leucaena esculenta*), which produces edible pods. The grasshopper *Sphenarium purpurascens*, a pest of maize, beans, alfalfa, and squash crops, functions as a generalist folivore in these native ecosystems. The stink bug *Nezara viridula*, notorious for damaging soybeans and legumes, is occasionally found in its natural habitat. In their native ecosystems, these species do not exhibit pest behavior, likely due to the presence of natural predators such as birds, insectivorous insects, and spiders like *Digueta* sp. Remarkably, in Oaxaca, *Quesada* and *Sphenarium* are traditionally consumed as alternative protein sources, and their collection may contribute to pest control. Preliminary findings suggest that agricultural practices leading to ecosystem simplification, particularly those that reduce predator populations, are key drivers of pest outbreaks. Conversely, the biodiversity of natural ecosystems and cultural practices, such as the consumption of insects as food, appear to play vital roles in pest regulation and merit further research.

Keywords— *Quesada gigas*, *Sphenarium purpurascens*, *Nezara viridula*, agricultural pests, native ecosystems, edible insects.

Expression of a New Microbial Lipase in Filamentous Fungus *Aspergillus Niger*

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Abstract:

Lipase has high economic importance and is widely used in different areas such as food, pharmaceutical, cosmetics, and detergent industries. The rapid development of synthetic biology has allowed the understanding and creation of technological systems for optimizing high-efficiency *Aspergillus niger* cell factories. One of the tools, the CRISPR/Cas9 system of gene editing technology can further improve the efficiency of building the modified lipase-producing *A. niger*. The objective of the work is to construct *Aspergillus niger* strains with putative lipase genes and test the recombinant lipases in an enantioselective reaction model. Primers were designed based on the sequences of genes found in the *A. niger* genome (<https://fungidb.org>). All vectors were constructed using the USER cloning technique, introduced in a plasmid containing CRISPR/Cas9 and transformed in protoplasts of *A. niger*. The double deletion of the genes ASPNIDRAFT2_1145520 and ASPNIDRAFT2_1181654 was confirmed by diagnostic PCR, phenotypic alterations. The platform for production of selected lipases was successfully built. For the next steps the genes of hypothetical lipases will be overexpressed and tested for its lipolytic and enantiomeric characteristics and compared to industrial lipases.

Keywords: Recombinant lipases, CRISPR/Cas9, *A. niger*

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Skin Tone Bias in Face Recognition: A Pipeline for Mitigation and Fairness

Ana M. Cabanas

Abstract—Face recognition (FR) systems have become increasingly prevalent in applications ranging from security and law enforcement to social media and consumer technology. However, these systems often exhibit biases related to ancestral background and skin tone, leading to unequal performance across different groups. Fairness in artificial intelligence (AI) is a critical concern, especially in FR systems, where biased outcomes can have significant societal implications. This article summarizes the latest research on skin tone bias in FR systems, examining factors contributing to these biases, such as dataset imbalance, algorithmic limitations, and image quality. This review particularly focuses on the underrepresentation and misclassification of individuals with darker skin tones. Emerging trends in bias mitigation are also discussed, including multimodal Explainable AI (XAI). Finally, we explore strategies to promote equity in this rapidly evolving field through a proposed pipeline for developing fairer FR systems.

Keywords—Face recognition, skin tone classification, fairness, bias mitigation.

I. INTRODUCTION

Predictive algorithms are increasingly influential in healthcare, security, and finance, yet they remain susceptible to biases from flawed data or algorithms [1]–[3]. In computer vision (CV), these biases often manifest as performance disparities across demographic attributes such as age, gender, and particularly skin tone [4], [5]. While inductive bias aids model generalization, societal biases—such as unequal treatment based on origin or ancestry—must be mitigated. Fairness, in AI and statistical contexts, refers to the equitable treatment of individuals across demographic groups, ensuring that attributes like skin tone or gender do not disproportionately affect outcomes. Research has established formal criteria to measure and mitigate these disparities. Achieving fairness in CV models requires careful dataset curation and training methodologies that minimize the undue influence of demographic attributes on model predictions.

Bias in face recognition (FR), particularly regarding skin tone, undermines AI reliability and fairness [1], [6]. The underrepresentation of diverse skin tones in training data, compounded by subjective classification methods [7], [8], limits the effectiveness and ethical deployment of deep learning (DL) models [9], [10]. Despite this, mitigation strategies remain unclear, raising ethical and legal concerns about AI’s “black box” decision-making in facial detection [11], recognition [12], surveillance [13], and medical diagnosis [14]. These systems can reinforce societal biases, leading to discriminatory outcomes in law enforcement and security [13]. Higher error rates for darker skin tones increase the risk of wrongful arrests and prosecutions, perpetuating systemic discrimination [15]. Additionally, FR applications in security and surveillance often subject specific demographic groups to disproportionate

scrutiny, amplifying ancestral and cultural biases present in training datasets [6], [13].

Research has consistently demonstrated performance disparities in FR across demographic groups [6]. The Gender Shades project found that commercial facial analysis algorithms exhibited significantly higher error rates for darker-skinned females, reaching 34.74% compared to only 0.8% for lighter-skinned males [16]. Similarly, NIST’s Face Recognition Vendor Test documented substantial variations in accuracy across ethnic groups [2]. Beyond accuracy, fairness-aware evaluations have revealed systematic biases in both false positive and false negative rates, reinforcing disparities in model outcomes across subpopulations [17].

This article delves into these challenges, with a specific focus on skin tone bias in FR. Drawing upon the latest research, we provide a comprehensive overview of the problem, exploring the concept of fairness in AI. We further discuss the complexities of achieving demographic parity in FR, emphasizing the need for careful consideration of data, algorithms, and evaluation metrics. As a step towards addressing these issues, we propose a pipeline designed to guide the development of more equitable FR systems.

II. SOURCES OF SKIN TONE AND DEMOGRAPHIC BIAS IN FR

A. Skin tone classification

Early work in machine learning fairness often relied on broad, ill-defined “racial” categories like “black” or “white” [18], a practice that continues in some recent CV applications [5], [19]. These categories are problematic due to their unstable, geographically variable, and culturally specific nature [20]. Therefore, recognizing the limitations and potential for misinterpretation of “race” from a genetic and social standpoint, we will use terms like “ancestry” and “demographic group” to more accurately reflect population diversity. Focusing on observable characteristics, such as skin tone or biometric features, offers more stable measures for assessing fairness [11], [16], and has revealed performance disparities for individuals with darker skin [19]. This has led to calls for improved skin tone measurement accuracy in the field [4], [8].

Traditionally, the Fitzpatrick Skin Type (FST) scale has been used, classifying skin into six types based on response to ultraviolet light [21]. However, the FST scale has limitations, particularly in representing darker skin tones [22], and concerns exist regarding its annotation standardization and validity [7]. The more recent Monk Skin Tone (MST) scale [23] offers a 10-shade alternative, but both FST and MST still rely on discrete categorization. In contrast, the Individual Typology

Angle (ITA) provides a continuous, objective measure of skin tone. Calculated as $ITA = \arctan\left(\frac{L^* - 50}{b^*}\right) \times \frac{180}{\pi}$, where L^* represents lightness and b^* the yellow-blue component in the CIE Lab* color space, ITA correlates strongly with skin pigmentation [21]. While ITA is considered reliable, its values can be influenced by environmental factors like lighting [7], [24], highlighting the need for robust measurement protocols.

B. Dataset imbalance

A significant contributor to skin tone bias in FR is the lack of diversity in training datasets. Studies have shown that models trained on datasets with limited diversity tend to exhibit higher error rates for underrepresented groups [25]. Many publicly available datasets, such as Labeled Faces in the Wild (LFW) [10] and CelebA [6], predominantly feature images of individuals with lighter skin tones. For instance, analysis of LFW found that over 75% of the faces were male and over 80% were individuals with lighter skin tones, making it a dataset with significant demographic imbalances in terms of gender and skin tone representation [?], [6]. This underrepresentation of darker-skinned individuals leads to models that are less accurate in recognizing and classifying faces with darker skin tones. While the IJB-A dataset provides greater skin tone diversity, it still contains only 15% of individuals with darker skin [6]. Training models on such skewed data can result in biased feature representations that fail to generalize well to underrepresented groups.

In response to these disparities, various datasets have been developed to assess group fairness [6]. Some datasets offer categorical demographic labels, such as BUPT-BalancedFace [26], VGGFace2 [12], or FairFace [27]. Others, such as RFW, VDDFace2 [28], and Diversity in Faces (DiF) [29], include phenotype annotations. However, even datasets labeled as “balanced” may still exhibit biases depending on geographic and phenotypic distributions [6], [30].

More recent datasets, like IDS-8 [31] and Causal Conversations [5], include explicit skin tone classifications using the Fitzpatrick Skin Type (FST) scale. While FST is widely used in dermatology and fairness evaluations, its discrete nature may not capture the full spectrum of skin tones present in real-world populations. To address this, integrating continuous skin tone measurements, such as the ITA, which measures skin tone on a continuous scale based on luminance and chromaticity, may be more suitable for automated fairness evaluations in FR models [30].

C. Algorithmic limitations and image quality

Even with diverse datasets, algorithmic limitations can contribute to bias. Many FR algorithms rely on features that may be less discriminative for darker skin tones, such as subtle variations in texture or contrast [32]. Moreover, the algorithms themselves may be designed and optimized in ways that implicitly favor the majority group in the training data. For example, some FR algorithms rely on detecting the location of facial features and calculating distances between them. However, this technique has been shown to misidentify subjects with darker skin tones more frequently than those with lighter

skin [28]. Notably, when used to identify “black” females, the error rate of these algorithms can be as high as 35% [6]. This discrepancy in accuracy across different demographic groups underscores a significant issue of bias within the current state of facial recognition technology, demanding further attention and refined solutions to ensure equitable performance.

Furthermore, variations in image quality and lighting conditions can exacerbate skin tone bias [24]. Images of individuals with darker skin tones may have lower contrast or be more susceptible to noise, particularly in suboptimal lighting. These factors can negatively impact the performance of FR systems, leading to higher error rates for darker-skinned individuals.

III. STRATEGIES FOR MITIGATING SKIN TONE BIAS

In machine learning, the assumption of identical and independent distribution between training and test sets often fails in CV, leading to an out-of-distribution (OOD) problem known as “dataset bias” [33]. This bias manifests in several forms: selection bias, where datasets lack diversity; capture bias, related to spatial and illumination variations; label bias, involving mislabeling; and negative set bias, which excludes certain appearances. Class imbalance, where certain classes are underrepresented in the dataset, can further exacerbate these biases [34]. The following strategies, though different in approach, are traditional techniques that can address these biases and the class imbalance problem [34], [35].

A. Data augmentation and balancing

An approach to mitigating bias is to augment existing datasets with more images of underrepresented groups. This can involve collecting new data or using techniques like data synthesis to generate artificial images of individuals with darker skin tones [30]. Another strategy is to balance the dataset by oversampling minority groups or undersampling the majority group. Generative Adversarial Networks (GANs) can also be used for generating synthetic images of underrepresented groups [36]. These synthetic images would provide a wider range of darker skin tones and facial features associated with these groups. Traditional strategies include data augmentation to expand dataset sizes through techniques like translation and rotation, though their effectiveness varies [37]. Synthetic data, particularly generated using GANs and techniques like Synthetic Minority Over-sampling Technique (SMOTE) [38], offer significant advantages over real-world data in FR systems. GANs like AttnGAN, IcGAN, and Re-AttrGAN [3] enable manipulation of facial attributes and demographics, aligning with desired distributions while ensuring consistency in verification and image quality across diverse groups [39]. These advancements not only address dataset imbalances but also enhance performance in critical applications such as FR. This approach helps mitigate biases and improve overall system accuracy, contributing to more equitable and effective AI applications.

B. Performance disparities and evaluation metrics

To address fairness in FR, evaluation metrics extend beyond traditional accuracy measures. Accuracy, defined as $\text{accuracy} = \frac{TP+TN}{TP+TN+FP+FN}$ assesses a model's ability to correctly classify identities, but it does not capture the differential impact across groups. False Positive Identification Rate (FPIR), given by $\text{FPIR} = \frac{FP}{FP+TN}$ and False Negative Identification Rate (FNIR), defined as $\text{FNIR} = \frac{FN}{FN+TP}$ are critical in evaluating fairness, as disparities in these rates can result in unequal societal consequences. Huebner et al. (2024) emphasized that fairness-aware modeling can mitigate these biases without significantly compromising accuracy, highlighting the importance of integrating fairness constraints in FR evaluation [17].

The choice of fairness metric depends on the application and the societal implications of errors. In law enforcement, high FPIR could lead to wrongful identifications, whereas in border security, high FNIR might hinder legitimate access. Ensuring parity across FPIR and FNIR is therefore essential for equitable FR deployment. Recent work in fairness-aware evaluation advocates for dynamic weighting of these metrics to reflect real-world consequences and mitigate disproportionate harm to marginalized groups [17].

C. Fairness-aware algorithms and post-processing adjustments

To address biases, researchers are developing algorithms that explicitly incorporate fairness constraints during training, aiming to minimize performance disparities across demographic groups while maintaining overall accuracy. One such technique is adversarial training, where a secondary network (the "adversary") attempts to identify the demographic group of a face, while the primary network simultaneously performs facial recognition while trying to prevent the adversary from succeeding, thus learning representations that are less sensitive to demographic attributes [40]. Another approach involves reweighing training samples based on their demographic group to compensate for dataset imbalance [41]. Similarly, regularization techniques add penalty terms to the loss function to discourage the model from learning biased representations. Beyond training, some methods focus on adjusting the output of FR systems after they have been trained. For instance, calibration techniques can adjust the system's thresholds or scores for different demographic groups to equalize error rates. These post-processing adjustments offer a way to mitigate bias in already deployed systems.

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IV. EMERGING TRENDS AND FUTURE DIRECTIONS

The increasing deployment of these technologies in social and governmental institutions underscores the need for robust ethical frameworks and regulatory oversight. Ensuring transparency, accountability, and fairness in FR systems is essential

to mitigate bias-related harms and uphold fundamental rights [15]. As the field advances, interdisciplinary research integrating computer vision, social sciences, and human-centered AI design will be crucial to developing FR models that are both equitable and ethically sound.

Several key trends are shaping the future of this area, including the development of multimodal XAI techniques that can provide more comprehensive explanations for model decisions by integrating information from multiple data sources. These techniques could be particularly relevant for FR systems that analyze complex visual data and other data types [42]. Simultaneously, researchers are moving away from broad, subjective categories towards objective, quantifiable scales for measuring skin tone, such as the Fitzpatrick Skin Type (FST) or Monk Skin Tone (MST) scale, enabling more precise and reliable assessments of skin tone diversity. Efforts are also underway to create larger, more diverse, and representative datasets that better reflect the global population, with the BOLD dataset [43] serving as a notable example, although concerns remain regarding dataset representativeness. Beyond dataset curation, dataset balancing techniques using generative models, such as GANs and latent diffusion models, have gained traction as a way to mitigate demographic imbalances [30]. However, such approaches must be carefully designed to prevent the unintended reinforcement of existing biases. A growing body of research suggests that fairness-aware augmentation, combined with dataset balancing and metric-based fairness evaluations, is necessary to ensure FR models remain equitable across diverse populations [30]. In addition, federated learning presents a promising avenue, allowing models to be trained on decentralized datasets without sharing the data itself, thus improving diversity while addressing privacy concerns.

Explainable AI (XAI) methods are also crucial for understanding and interpreting the decisions made by increasingly complex AI models, especially deep learning models. XAI enhances transparency, trust, and fairness by validating decisions against domain knowledge and mitigating biases that could disadvantage certain groups [44]. Key techniques in this area include SHapley Additive exPlanations (SHAP), which attributes each feature's contribution to the model's prediction based on cooperative game theory [45], and Local Interpretable Model-agnostic Explanations (LIME), which approximates local model behavior by perturbing input data to explain individual predictions [11]. Saliency maps highlight regions in input data that most influence predictions, providing a visual representation of the model's focus [11], with techniques like Gradient-weighted Class Activation Mapping (Grad-CAM and Grad-CAM++) offering more detailed and class-discriminative visualizations compared to traditional saliency maps and can be applied to CNN architectures without modifications.

Interestingly, recent research suggests that skin color might not be as crucial for the internal feature learning of deep convolutional neural networks (CNNs) in FR as initially thought [46]. This study indicates that CNNs trained exclusively on grayscale images can achieve performance comparable to those trained on color images, suggesting that these models primarily rely on structural and textural features for identification, similar to achromatopsia, where color vision is absent

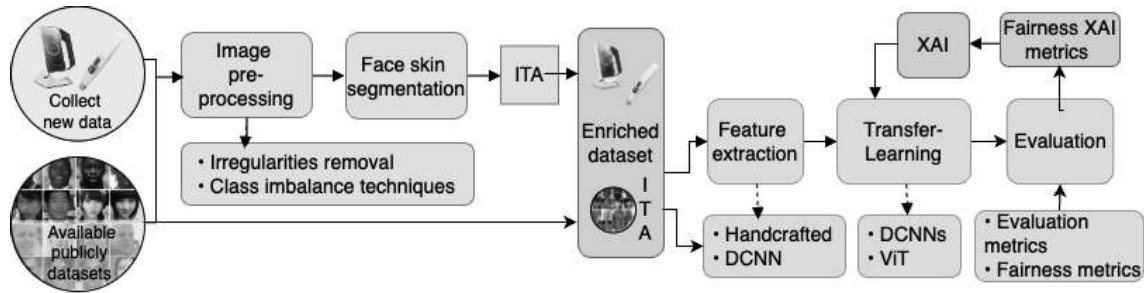


Fig. 1. Methodology pipeline for a fairer facial recognition system, divided into three phases: Data Acquisition and Preprocessing (blue) focusing on diverse data and objective skin tone measurement (ITA); Model Development and Training (green) using feature extraction and transfer learning; and Model Evaluation and Explanation (pink) incorporating fairness metrics and Explainable AI (XAI) techniques.

[46]. However, it is important to note that biases can also be introduced through variations in these very structural or textural features, often referred to as biometric features, which can be influenced by factors correlated with skin tone or demographic background [9], [11]. While color may be less critical during feature extraction, research shows that skin tone influences similarity scores, necessitating careful threshold adjustments for equitable performance across demographic groups [19]. This underscores the complex role of skin tone in facial recognition, indicating that while perhaps not essential for core model training, it is a crucial factor in achieving fairness during real-world application.

To systematically mitigate bias in facial recognition, a structured pipeline is essential. As shown in Figure 1, the proposed methodology comprises three key phases: data acquisition and preprocessing, model development and training, and model evaluation and explanation. The process begins with facial image data acquisition, either through new data collection—prioritizing diverse skin tones and objective metrics like the ITA—or by leveraging public datasets while carefully assessing their diversity and limitations. From publicly available datasets, a method for objectively and precisely extracting color, as described in [24], should be implemented to ensure accurate skin tone measurement. The collected data then undergoes preprocessing to enhance image quality and consistency through noise reduction, illumination correction, and, if necessary, class imbalance techniques. Accurate facial region segmentation and objective skin tone computation ensure standardized measurement across images.

In the model development and training phase, a crucial decision is whether to train directly on processed facial images or extracted features. Feature extraction may involve handcrafted features tailored to facial characteristics and skin tone variations or deep learning models like DCNNs or Vision Transformers (ViTs) for automated feature learning. Transfer learning, using pre-trained models on large datasets, is often employed to improve performance, particularly when training data is limited. Fairness-aware training strategies such as adversarial debiasing and mutual information minimization help ensure that predictions are based on identity-related features rather than sensitive attributes like skin tone.

The final phase involves rigorous model evaluation and explanation. Performance can be assessed using standard metrics—accuracy, precision, recall, F1-score, and

AUC—alongside fairness metrics to detect disparities across skin tone groups. The pipeline supports an iterative approach, where evaluation findings and XAI insights drive further data collection, model refinement, or feature re-evaluation. This process, integrating objective skin tone measurement at every stage, enhances fairness and transparency in facial recognition systems.

V. CONCLUSIONS

The pervasive deployment of face recognition technology necessitates robust ethical frameworks and regulatory oversight to mitigate bias-related harms and uphold fundamental rights. Addressing skin tone bias, a significant challenge in FR, requires a multi-faceted approach. This includes improving dataset diversity, developing fairness-aware algorithms, and promoting transparency through Explainable AI techniques. Furthermore, the complex role of skin tone in facial recognition requires further investigation; while it may not be essential for core model training, it remains a crucial factor in achieving fairness during real-world application. As the field advances, interdisciplinary research, integrating computer vision, social sciences, and human-centered AI design, will be crucial for developing FR models that are both equitable and ethically sound. Ultimately, ongoing research and development, including the exploration of multimodal XAI and the proposed pipeline emphasizing diverse data collection and objective skin tone measurement, hold the key to creating FR systems that are both accurate and fair across all demographic groups.

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Evaluating the Environmental Benefits of Smart Inverters in a 100 MW Solar PV Plant: A Smart Grid Case Study in Kuklibeg, Kosovo

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Abstract

This study evaluates the environmental and technical benefits of integrating smart inverters in a 100 MW solar PV system. Using Kuklibeg, Kosovo as a case study, two scenarios were analyzed: one with traditional inverters and another with smart inverters. RETScreen software was used to assess energy production potential, CO₂ emissions, and climatic suitability. MATLAB scripting supported the simulation of inverter performance, including output energy, efficiency, and losses. Results indicate that smart inverters increase AC output by optimizing energy conversion and improve overall system efficiency. The average CO₂ reduction improved from 124,923 tCO₂/year to 128,868 tCO₂/year, marking a relative gain of 3.16%. While inverter efficiency did not significantly impact the surface area required, PV module efficiency optimized selection reduced land use from 467,520 m² to 454,960 m². This analysis shows that deploying smart inverters, combined with efficient PV technologies, leads to higher productivity, less CO₂ emissions, and more compact land use for the same installed capacity. These findings reinforce the importance of smart grid components in enhancing environmental and energy performance in large scale PV projects, especially in emerging renewable energy markets like Kosovo.

Keywords: Smart inverters, Solar PV system, CO₂ emissions reduction, RETScreen simulation, Renewable energy optimization.

Introduction

As global environmental policies become increasingly strict, the urgency to address climate change has accelerated the global shift toward clean energy solutions [1]. In this context, renewable energy sources play a crucial role not only in sustainable energy production but also in reducing environmental impact. Optimizing all components involved in renewable energy systems, particularly those responsible for energy conversion is essential. Such optimization contributes to higher energy output from the same installed capacity, reduced land usage, and lower CO₂ emissions [2].

One of the most critical components in renewable energy systems is the inverter, which converts direct current (DC) generated by photovoltaic (PV) panels into alternating current (AC) suitable for grid integration and consumption. Several studies [3], [4] have highlighted the importance of inverter feasibility, especially in large scale renewable energy systems, where even a small variation in inverter efficiency can significantly impact overall energy output. While the majority of research, including [5]–[8], has focused on PV panel technologies, particularly in relation to land use efficiency, the role of inverters remains as essential as PV panels. Proper selection and optimization of inverter technologies are crucial not only for maximizing energy output from a given installed capacity but also for minimizing CO₂ emissions in grid connected systems.

The purpose of this study is to highlight the significant impact that inverter efficiency can have on climate change, even though it may seem like a small technical detail. This factor should be prioritized over simply

increasing project costs, as improving inverter efficiency can lead to better environmental outcomes without major capital investment. Two software tools, MATLAB and RETScreen, were used due to their accuracy and reliability. These tools have also been utilized in numerous other studies, such as [9] and [10], for energy production modeling and emission reduction analysis.

The selected location for the study is Kuklibeg, Kosovo, which was chosen because of its high potential for solar photovoltaic (PV) installations. According to solar radiation zoning maps of Kosovo [11], this area receives some of the highest solar irradiance in the country, making it an ideal candidate for feasibility analysis and renewable energy integration.

This study aims to provide an accurate feasibility assessment of selecting appropriate equipment to optimize both energy output and environmental performance. Its primary contribution leads in the comparative analysis between traditional and smart inverters, as well as between different types of PV panel manufacturers. The study evaluates their impact on CO₂ emission reduction, land use efficiency, and other relevant factors, offering valuable insights that can inform future policy development at the national level.

Methodology

This study employs two widely used simulation tools: MATLAB and RETScreen.

MATLAB (Matrix Laboratory) is a high-performance language and environment for numerical computation, simulation, and algorithm development. It is particularly well-suited for modeling complex energy systems, including PV arrays and power electronics, due to its flexibility and integration with Simulink [12].

RETScreen is a clean energy management software developed by Natural Resources Canada. It is designed to evaluate the energy production, life-cycle costs, emission reductions, financial viability, and risk for various types of renewable and non-renewable energy technologies [13].

The inputs given to MATLAB for the simulation included:

- Installed capacity: 100 MW
- PV panel capacity (individual module)
- Inverter efficiency (two scenarios: traditional and smart)
- Total number of PV modules
- Number of strings and modules per string
- Voltage per string
- Traditional Inverter efficiency
- Smart Inverter efficiency
- Panel efficiency
- Land area required

These parameters were selected based on average data from multiple solar panel manufacturers and inverter providers, as illustrated in Figure 1, which shows the input values used in the MATLAB script.

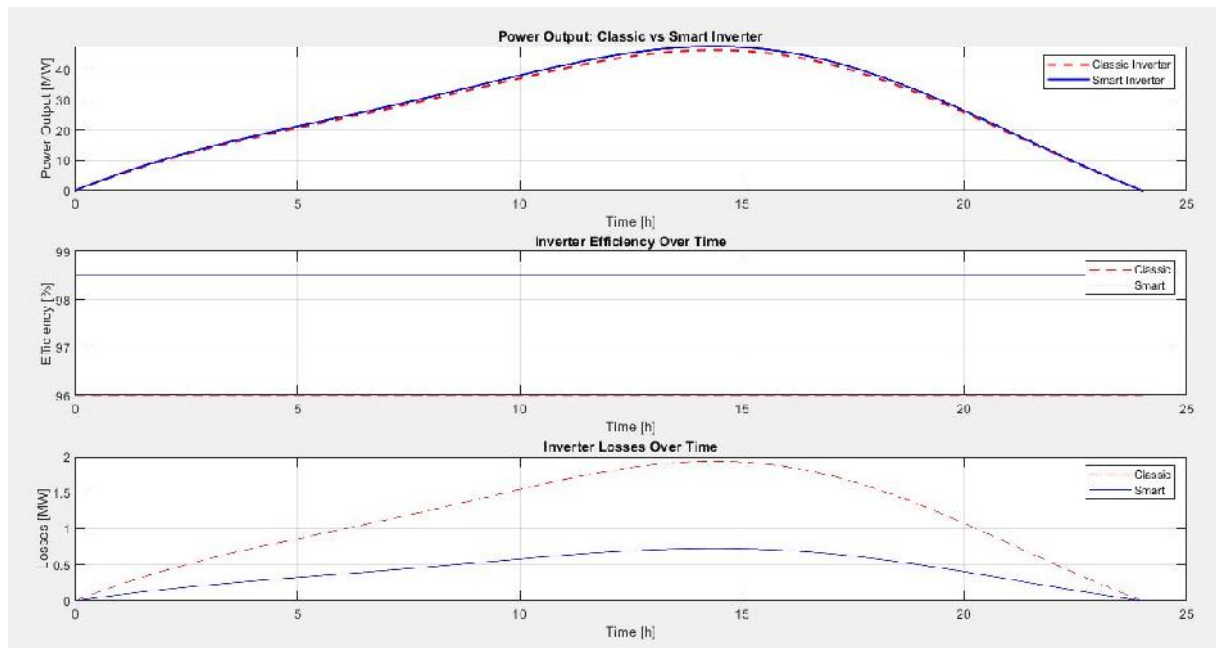


Figure 1. Comparison Between Traditional and Smart Inverters for Power Output, Efficiency, and Losses

In RETScreen, as can be seen in Figure 2 below, the geographic location selected was Kuklibeg, Kosovo. The climate database embedded in RETScreen was used to extract meteorological conditions, including solar irradiance, ambient temperature, and precipitation for the site.

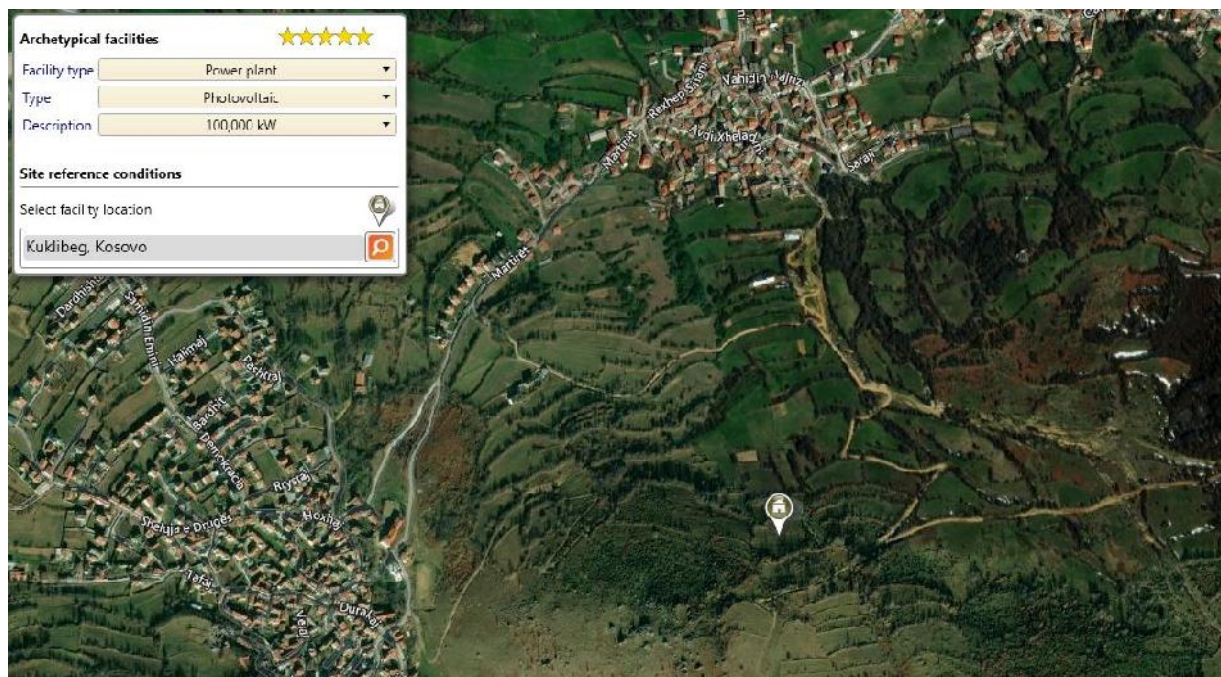


Figure 2. Location chosen in RETScreen

As it can be seen from Figure 3, the daily solar radiation at the selected location is relatively high, especially during the months from April to August, where values exceed $6 \text{ kWh/m}^2/\text{day}$, peaking around 7

kWh/m²/day in July. This clearly indicates that the site has excellent solar potential and is suitable for photovoltaic (PV) installation throughout the year. The average annual solar radiation remains consistently favorable for energy production.

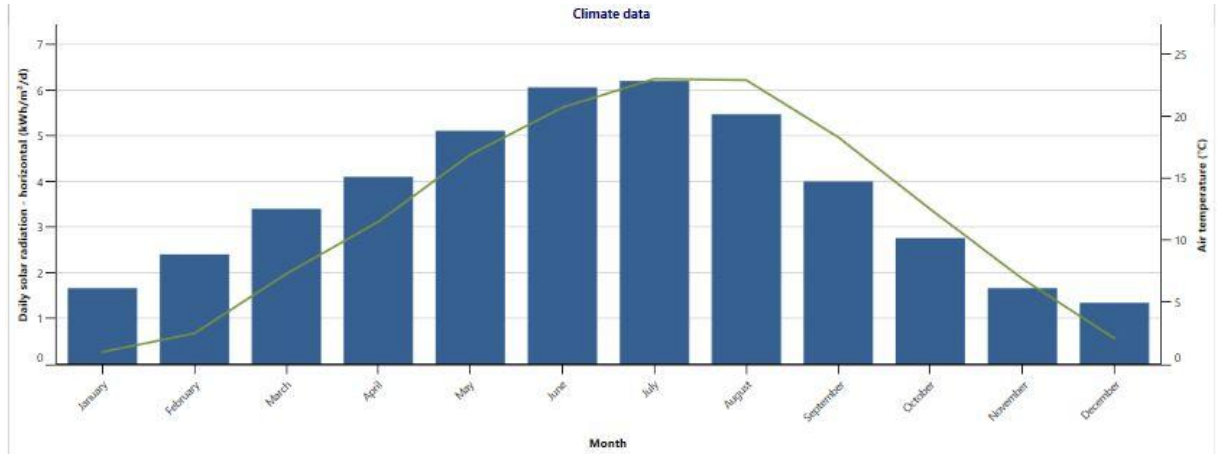


Figure 3. Climate datas for the location calculated from RETScreen

According to RETScreen data, the climate data used in the analysis, including daily solar radiation and air temperature, are sourced from NASA's satellite database. This adds a level of credibility and accuracy to the resource assessment, ensuring that the PV project is based on reliable and globally recognized datasets.

The comparative analysis between traditional and smart inverters was based on their efficiency, denoted by the formula:

$$\eta = \frac{P_{out}}{P_{in}} \quad (1)$$

Where:

- P_{in} is input DC Power to the Solar Panels, and
- P_{out} is the output AC power given to the load.

The CO₂ emission reduction in RETScreen is computed automatically based on the baseline fossil fuel system versus the renewable system, using the formula:

$$\Delta E_{CO_2} = E_{fossil} - E_{renewable}$$

Where:

- E_{net} is the net annual electricity generated [MWh/year]
- EF is the emission factor [tCO₂/MWh] based on national grid intensity.

For Kosovo, EF value is 1.02 tCO₂/MWh, including T&D losses [14].

Land use can be calculated with the below formula:

$$L = N \times A_m \times A_s$$

Where:

- A_m is the area of a single module
- A_s is accounts for walking lanes, tilt, and thermal spacing.

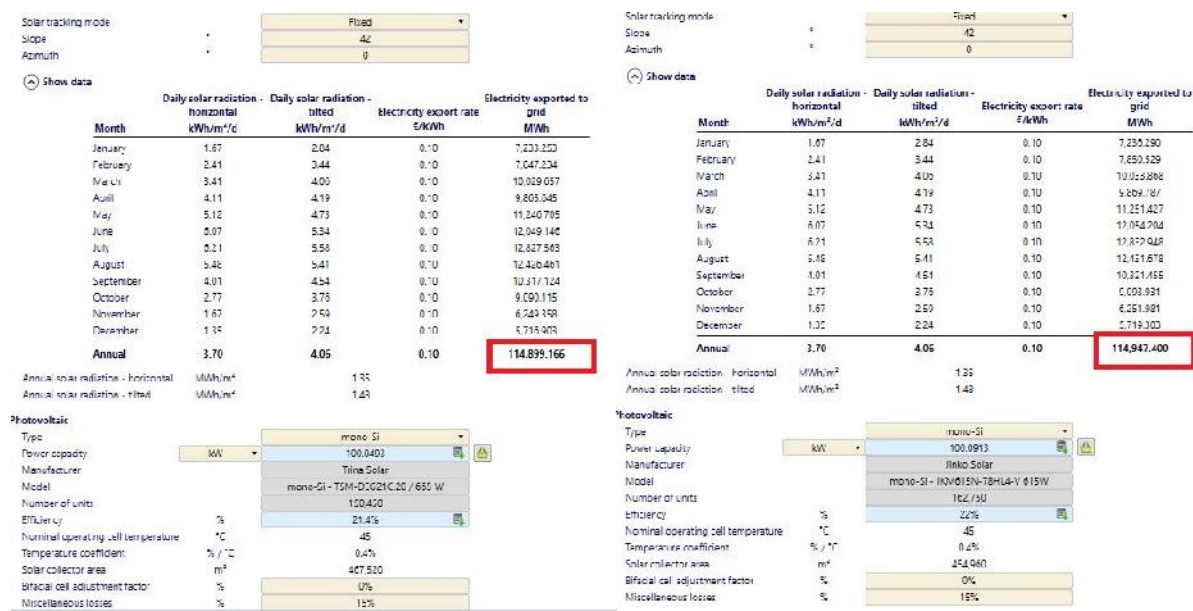
These parameters enabled a detailed scenario-based analysis to assess the benefits of smart inverters in improving energy yield, reducing land footprint, and lowering greenhouse gas emissions.

1.1 Comparison Analysis Based on RETScreen and MATLAB Data

In addition to the use of software tools, a comparative analysis was conducted using data from RETScreen and MATLAB. The first comparison focuses on the performance difference between traditional and smart inverters, using MATLAB-generated data based on average values from several PV module manufacturers.

Another comparison was performed using the RETScreen database of photovoltaic manufacturers, where Trina Solar and Jinko Solar were selected as representative technologies based on default system settings. The analysis compared their maximum power per panel, assuming identical inverter efficiency of 98% in both cases.

Figure 3 present the annual energy production for the same installed capacity (100 MW) using different types of PV panels. These comparisons help quantify the impact of panel selection and inverter technology on total energy output and system efficiency.



Based on RETScreen simulation, both Trina Solar and Jinko Solar panels installed at 100 MW capacity under identical conditions show nearly equal annual energy output. Jinko Solar produced 114,947 MWh, slightly more than Trina Solar's 114,899 MWh, a difference of only 48 MWh per year. This marginal gain is due to Jinko's higher panel efficiency (22.0% vs. 21.45%), confirming that panel type slightly influences total energy production even when inverter efficiency and system size remain constant.

Results

Energy output for different scenarios

This chapter presents the comparative analysis results of the annual energy output from a 100 MW photovoltaic (PV) system, based on different combinations of inverter technologies (traditional vs. smart) and PV panel manufacturers (Default, Jinko Solar, and Trina Solar). The main objective was to assess how inverter efficiency and module performance impact the total electricity exported to the grid, with a focus on maximizing energy yield and minimizing CO₂ emissions.

In the table below are given datas earned from RETScreen, after inputs were given:

Table 1. Annual energy output from 100MW PV system based on different inverter technologies

	Scenario	Inverter Efficiency	Panel Brand	Annual Energy Output (MWh)
0	Default	0.95	Default	114842.606
1	Default	0.98	Default	118469.215
2	Jinko	0.95	Jinko Solar	114947.4
3	Jinko	0.98	Jinko Solar	118469.215
4	Trina	0.95	Trina Solar	114899.166
6	Trina	0.98	Trina Solar	118527.561

The first scenario analyzed was the default setup using average system parameters. With a traditional inverter efficiency of 0.95, the system produced 114,842.606 MWh annually. When the same system was simulated with a smart inverter at 0.98 efficiency, the output increased to 118,469.215 MWh, an improvement of approximately 3,626 MWh or 3.16%. This gain demonstrates the direct benefit of using smart inverters, especially in large scale systems.

Subsequently, two manufacturers, Jinko Solar and Trina Solar, were assessed under both inverter efficiency scenarios. For Jinko Solar, the energy output was 114,947.400 MWh with traditional inverters and increased to 118,527.561 MWh using smart inverters, resulting in a gain of 3,580 MWh. Similarly, for Trina Solar, the output rose from 114,899.166 MWh with traditional inverter to 118,527.561 MWh with smart inverter, leading an increase of approximately 3,628 MWh annually.

These results consistently show that regardless of panel manufacturer, improving inverter efficiency from 95% to 98% leads to a noticeable increase in total energy production. Given similar capital investment, this directly translates to a lower cost per MWh generated, reduced emissions per energy unit, and more efficient land use.

In conclusion, the findings strongly support the adoption of smart inverter technologies in large-scale PV projects in Kosovo and beyond, as they offer measurable energy and environmental benefits.

In the figure below, the comparative results discussed previously are presented graphically, illustrating the annual energy output for each PV configuration using both traditional and smart inverters. The chart clearly highlights the performance improvement achieved with smart inverters across all panel types.

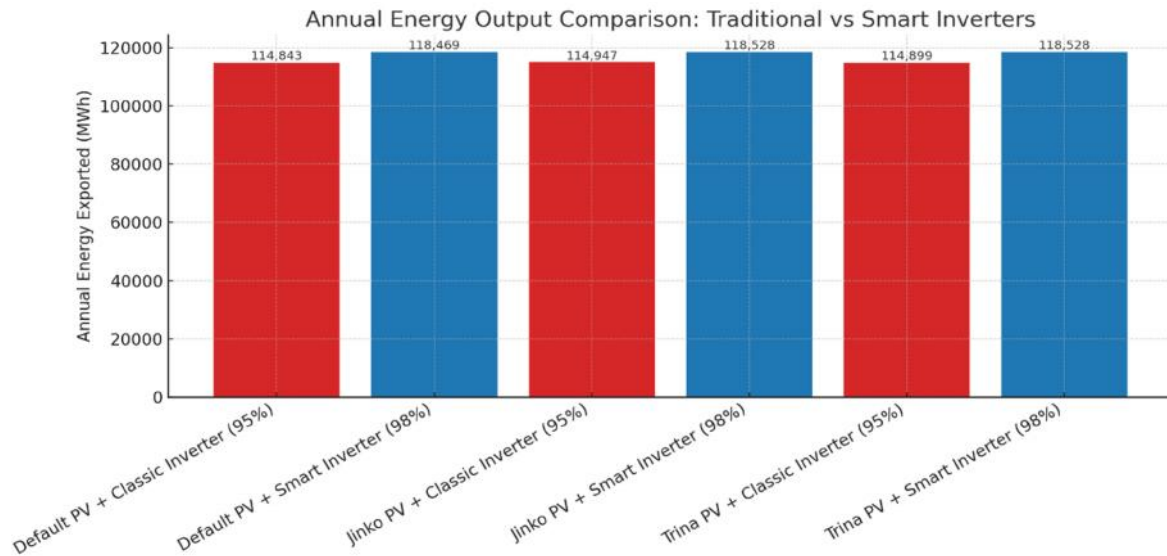


Figure 4. Comparative results of annual energy output of different scenarios used in the study

1.2 CO₂ Emission Reduction Based on Inverter Type

As illustrated in the figure below, a clear comparison is made between the use of traditional default inverters with efficiency of 0.95 and smart inverters with efficiency of 0.98 in terms of CO₂ emission reduction. According to RETScreen's emission analysis, the system equipped with traditional inverters results in a gross annual GHG emission reduction of 124,923 tCO₂, while the use of smart inverters increases this reduction to 128,868 tCO₂. This difference confirms that the higher efficiency of smart inverters directly contributes to greater mitigation of greenhouse gas emissions. Therefore, improving inverter efficiency, even by a few percent, plays a significant role in reducing the environmental impact of large-scale PV systems.



Figure 5. CO₂ emission reduction by using traditional and smart default inverters calculated by RETScreen

In this part of the study, a detailed emission analysis was performed using RETScreen to evaluate the potential CO₂ emission reduction for six different photovoltaic system configurations. Each scenario was simulated by varying two parameters: the type of inverter used (traditional with 95% efficiency and smart with 98% efficiency), and the photovoltaic panel manufacturer (Default RETScreen, Jinko Solar, and Trina

Solar). For each case, the annual energy exported to the grid was entered into the emissions module to determine the gross annual GHG (CO₂) reduction compared to a baseline scenario.

The results are summarized in the table below. As shown, the use of smart inverters consistently results in higher CO₂ reductions than traditional inverters. For instance, the combination of Jinko panels with a smart inverter achieves the highest reduction, with 128,986 tCO₂ annually. Even small differences in inverter efficiency, when scaled to a 100 MW plant, show significant environmental impact. Across all configurations, the smart inverter outperforms its traditional counterpart by reducing an additional 3,800–4,100 tons of CO₂ annually, depending on the panel used.

Table 2. RETScreen evaluation of the potential CO₂ emission reduction for six different photovoltaic system configurations

	Scenario	Exported Energy (MWh)	CO ₂ Reduction (tCO ₂ /year)
0	Default Inverter (95%)	114843	124923
1	Default Smart Inverter (98%)	118469	128868
2	Jinko + Inverter 95%	114947	125037
3	Jinko + Smart 98%	118577	128986
4	Trina + Inverter 95%	114899	124985
5	Trina + Smart 98%	118528	128932

These values clearly demonstrate the positive environmental impact of adopting higher efficiency inverters, not only by increasing total energy output but also by significantly reducing greenhouse gas emissions. While the choice of panel manufacturer also affects the total energy output due to slight variations in efficiency and design, the inverter type shows a more consistent and measurable influence on emission reduction.

To visually support this analysis, the table above is also illustrated in the graph below, providing a comparative view of all six scenarios with their respective CO₂ reduction values.

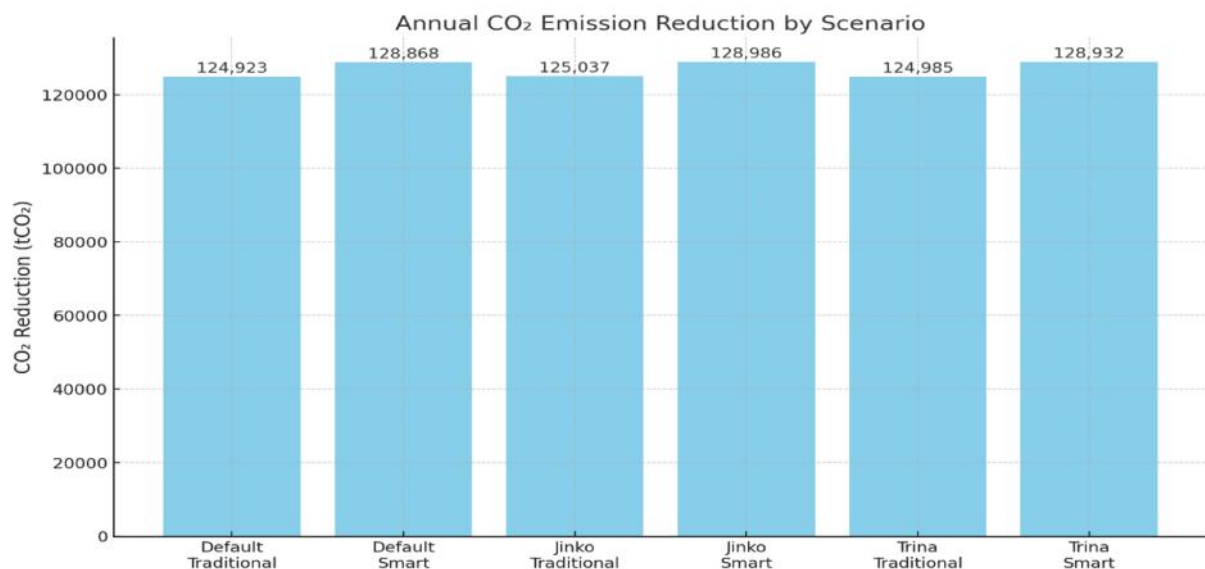


Figure 6. Six scenarios of CO₂ emission reduction

Conclusion

The comprehensive analysis conducted in this study clearly highlights the impact of inverter efficiency and panel type on both energy production and CO₂ emission reduction in a 100 MW solar power plant scenario in Kosovo. Across six configurations involving traditional and smart inverters of Default, Jinko, and Trina panels, the results consistently demonstrate that smart inverters, these with 98% efficiency significantly improve system performance compared to traditional inverters with approx.95% efficiency.

From the energy production perspective, systems equipped with smart inverters delivered higher annual electricity output to the grid, on average about 3.6 to 4.0 GWh more compared to their traditionals. For example, the energy exported to the grid using Jinko panels increased from 114,947 MWh to 118,527 MWh when switching from traditional to smart inverters. This enhancement directly correlates with improved conversion efficiency and reduced system losses.

In terms of environmental impact, CO₂ emission reductions followed the same trend. The smart inverter configurations consistently achieved greater emission savings, approximately 4,000 tonnes of CO₂ more per year across all panel types. The highest reduction was achieved in the Jinko with smart inverter case, reaching 128,986 tCO₂/year, whereas the lowest was seen in the Default with traditional inverter case with 124,923 tCO₂/year.

These findings confirm that smart inverters are a critical technological upgrade not only for increasing energy output but also for maximizing the environmental benefits of solar energy deployment. Regardless of panel brand or specifications, investing in high efficiency inverters provides measurable gains in clean energy output and carbon mitigation, supporting both energy security and climate goals.

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Image Recognition Technology for Urban Waste Classification

Abdul Musawer Danish

Abstract— The urban population in developing countries keeps overgrowing, so does the amount of generated municipal solid waste in cities worldwide. It is also the case of Kabul City, the capital city of Afghanistan, where there is still no appropriate solid waste management system. Currently, Kabul (with its 5000,0001) and still growing population, is having difficulties managing its municipal solid waste. This can be mostly attributed to the fact that Kabul city's typical solid waste management system -collect and dump to the landfill area. As solid waste piles and stays long in the street before it is collected, on windy days the piled up solid waste spreads in the city, while on rainy days it spreads, even more, making its way into roadside drainage, clogging them, causing numerous problems, including direct and/or indirect economic as well as health issues. This research addresses household and mixed-use generated solid waste. The proposed solution is twofold: (i) an ICT-based management system and (ii) the conversion of solid waste into a resource. In a multiple-use area, the solid waste is detected by the camera and classified by ImageJ. This enables and optimized collection of the categorized solid waste for an efficient transportation to corresponding plants to produce energy. Hopefully, the proposed solution will enhance the capacity of the Kabul city municipal solid waste problem.

Keywords— urban population, developing countries, municipal solid waste, solid waste management.

Sustainable Textile Processing Using Microbial Biosurfactants

Filipa Soares, Rita Beiral, Marilia Berezuk, Isabel Alves, Aurore Loudet, Nádia Eusébio

Abstract— The increasing exploitation of natural resources and industrial activities have led to significant environmental degradation. Petroleum-based products, particularly surfactants used across various industries, are a major source of pollution due to their low biodegradability. While plant-based surfactants have been proposed as greener alternatives, they often require extensive agricultural resources, including land, water, and fertilizers, which can contribute to deforestation and food supply competition. In contrast, microbial biosurfactants offer a more sustainable and efficient solution, as they can be produced using renewable waste substrates, exhibit superior biodegradability, lower toxicity and perform effectively under a wide range of environmental conditions. This study explores the potential of biosurfactants in textile processing as sustainable substitutes for conventional scouring and bleaching agents. Laboratory and Industrial-scale experiments were conducted to evaluate the application of microbial biosurfactants in textile treatment. Fifteen different biodegredients were formulated, each containing distinct biosurfactants, to assess their effectiveness in fabric processing. The study examined their ability to remove impurities, enhance fabric wettability, and facilitate subsequent dyeing and finishing processes. Comparative analyses were performed against conventional scouring and bleaching treatments, fabric hydrophilicity, and whiteness levels. Each formulation was tested under controlled conditions to determine its efficiency. Preliminary findings demonstrate that biosurfactants effectively eliminate hydrophobic contaminants and enhance fiber wettability at lower temperatures. Cotton and synthetic fabrics treated with biosurfactants exhibited comparable hydrophilicity and whiteness levels to conventional bleaching methods. These results highlight the feasibility of incorporating biosurfactants into textile processing as a greener alternative. The adoption of biosurfactant-based textile treatments could mark a paradigm shift toward more environmentally responsible manufacturing practices. By reducing dependence on synthetic chemicals, lowering energy demands, and minimizing wastewater contamination, this approach aligns with global sustainability goals and regulatory pressures for cleaner production methods. Future research will focus on scaling up biosurfactant production, optimizing formulations for different fabric types, and evaluating long-term performance in industrial applications. Microbial biosurfactants represent a promising biotechnological innovation for sustainable textile processing. Their ability to facilitate effective scouring and bleaching offers a viable alternative to conventional treatments, paving the way for a cleaner textile industry. This study contributes to the growing body of research on green chemistry solutions in textiles and underscores the importance of leveraging microbial biotechnology to drive sustainable industrial transformations.

Keywords— microbial biosurfactants, sustainable textiles, biodegredients, eco-friendly surfactants.

The Effect of Hybrid SPD Process on Mechanical Properties, Drawability, and Plastic Anisotropy of DC03 Steel

Karolina Kowalczyk-Skoczylas

Abstract— The hybrid SPD process called DRECE (Dual Rolls Equal Channel Extrusion) combines the concepts of ECAP method and CONFORM extrusion, and is intended for processing sheet-metal workpieces. The material in the form of a metal strip is subjected to plastic deformation by passing through the shaping tool at a given angle α . Importantly, in this process the dimensions of the metal strip do not change after the pass is completed. Subsequent DRECE passes allow for increasing the effective strain in the tested material. The method has a significant effect on the microstructure and mechanical properties of the strip. The experimental tests have been conducted on the unconventional DRECE device in VŠB Ostrava, the Czech Republic. The DC03 steel strips have been processed in several passes

- up to six. Then, both Erichsen cupping tests as well as static tensile tests have been performed to evaluate the effect of DRECE process on drawability, plastic anisotropy and mechanical properties of the investigated steel. Both yield strength and ultimate tensile strength increase significantly after consecutive passes. Drawability decreases slightly after the first and second pass. Then it stabilizes

on a reasonably high level, which means that the steel is characterized by useful drawability for technological processes. It was investigated in the material is characterized by a normal anisotropy. In the microstructure, an intensification of the development of microshear bands and their mutual intersection is observed, which leads to the fragmentation of the grain into smaller volumes and, consequently, to the formation of an ultrafine grained structure. "The project was co-financed by the European Union within the programme "The European Funds

for Śląsk (Silesia) 2021-2027".

Keywords— SPD process, low carbon steel, mechanical properties, plastic deformation, microstructure evolution.

Circular Economy Indicators in the Wooden Construction Sector

Spadaro Ottavio, Matarazzo Agata, Garraffo Francesco, Martelli Andrea

Abstract— The construction sector is among the most resource-intensive industries and one of the largest contributors to greenhouse gas emissions. Companies are increasingly implementing tools to reduce the environmental impact of construction activities, considering emissions, resource consumption, and waste management. This research examines the concept of the circular economy within the construction sector, analyzing strategies and practices aimed at minimizing waste and promoting material reuse, with a particular focus on technological innovations. The study explores circular economy indicators in sustainable construction through a critical literature review and an analysis of various models used to measure and assess environmental performance in green buildings. Additionally, it evaluates the economic and environmental benefits of adopting circular practices in the construction industry, providing insights for future developments and further research. As a case study, this thesis analyzes circular economy indicators applied to a Sicilian company specializing in wooden constructions located in Bronte, a town at the foot of Mount Etna. The company is one of the leading firms in Sicily's sustainable construction sector and has long been committed to environmental protection. A comprehensive assessment is conducted, involving the quantification and measurement of each indicator to determine whether the company meets the required standards and to evaluate the potential ethical and economic benefits of compliance. Adhering to these indicators fosters trust among environmentally conscious customers who prioritize recycling, reuse, and waste reduction. Moreover, compliance with circular economy principles can lead to increased sales, as customers tend to prefer sustainable companies when prices are comparable.

Keywords— environmental sustainability, circular economy, wooden construction, new materials.

Developing a Sustainable Burger to Reduce Uk Food Waste: Properties Analyses

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Maduabuchi is an independent researcher and an MSc graduate of Food and Nutrition Sciences at Sheffield Hallam University, United Kingdom. Hayley, a member of staff at Sheffield Business School, Sheffield Hallam University, supervised this research.

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Abstract

Background: Food waste remains a global challenge, with approximately 10.7 million metric tonnes discarded annually in the UK, including significant volumes of potatoes. This study addresses this issue by developing a sustainable, plant-based burger using whole potatoes.

Method: A mixed-methods design was adopted. Following ten trials, two potato-enriched burgers (Samples E and F) and one standard burger (Sample 1) were formulated. A Qualtrics survey gathered data from 160 UK adults to assess perceptions of food waste and sustainability (data retained for future analysis). Nutritional properties, protein, moisture, fat, and texture profiles, were analysed using standard techniques. Sensory evaluations were conducted with 37 untrained panellists using Redjade software, and results were statistically analysed using SPSS.

Findings: Protein content (13.03–19.57 g/100 g) was not significantly different ($p > 0.05$) across the samples. However, moisture and fat contents varied, ranging from 13.03 to 19.57 g/100 g and 44.17 to 56.80 g/100 g, respectively. Significant differences in texture were observed: Sample 1 recorded the highest hardness (3891.45 g) and chewiness (2055.51). Sensory data indicated notable differences in appearance (5.70–6.65) and texture (5.32–7.03), with Sample E scoring highest in appearance and overall liking (6.73), while Sample F led in texture.

Conclusion: Incorporating whole potatoes into plant-based burgers offers a sustainable strategy to reduce food waste while promoting innovation in food systems. This study highlights the potential for such products to bridge gaps in policy, consumer behaviour, and economic viability.

Keywords: Sustainable food innovation, Food waste, Consumer acceptance, Nutritional value, Regulatory framework.

ePAM: Advancing Sustainable Mobility through Digital Parking, AI-Driven Vehicle Recognition, and CO₂ Reporting

Robert Monsberger

Abstract—The increasing scarcity of resources and the pressing challenge of climate change require transformative technological, economic and societal approaches. In line with the European Green Deal's goal of achieving net-zero greenhouse gas emissions by 2050, this paper presents the development and implementation of an electronic parking and mobility system (ePAM). This system provides an integrated solution that aims to promote climate-friendly mobility, reduce individual vehicle use and drive the digital transformation of off-street parking. Key objectives include the accurate detection of electric vehicles and occupant numbers using advanced camera-based systems with very high accuracy. This capability will enable dynamic categorization and classification of vehicles to provide fair and automated tariff adjustments. The project also aims to replace physical barriers with virtual 'digital gates' using augmented reality, which has been shown in studies to significantly improve user acceptance. The system is designed to operate as an end-to-end software solution, enabling a fully digital and paperless parking management system by using license plate recognition (LPR) and metadata processing. By eliminating physical infrastructure such as gates and terminals, the system significantly reduces resource consumption, maintenance complexity and operating costs, while improving energy efficiency. The platform also integrates CO₂ reporting tools to support compliance with upcoming EU emissions trading schemes and to incentivize green transport behaviours. By promoting the use of electric vehicles and ride-sharing models, the system helps to optimize traffic flows in urban centres. The platform's open data interfaces enable seamless integration into multimodal transport systems, facilitating the transition from individual to public transport. This project emphasizes sustainability, data protection and compliance with the AI-Act, and aims to achieve a significant market share of at least 4.5% in the DACH region by 2030. ePAM sets a benchmark for innovative mobility solutions and drives significant progress towards climate-neutral urban mobility.

Keywords—Sustainable Mobility, Digital Parking, AI-Driven Vehicle Recognition, CO₂ Reporting, License Plate Recognition, Virtual Digital Gates, Multimodal Transport Integration.

I. INTRODUCTION

URBAN centres are increasingly struggling with traffic congestion, carbon emissions and inefficient parking infrastructure. The ePAM project directly addresses these challenges by integrating AI-driven vehicle detection, dynamic CO₂ reporting and digital parking solutions. These innovations not only promote sustainable mobility but also increase user convenience and operational efficiency.

Shoup [1] argues that parking issues are primarily political

rather than technological. ePAM uses advanced technology to support sustainability and circular economy principles.

To facilitate both the development and funding of this approach, a research funding application was submitted and subsequently approved. In addition, this paper explores the global relevance of such systems in achieving and supporting long-term sustainability goals, positioning ePAM as a key contributor to the future of urban mobility.

II. RESEARCH FUNDING

The Austrian Research Promotion Agency (Österreichische Forschungsförderungs-gesellschaft mbH, FFG) supports research, development and innovation projects on a wide range of topics with specific focuses. It provides funding and support for newcomers, individual projects, large cooperative initiatives and centres of excellence. In addition, FFG strengthens the internationalization of Austrian science, research and technology, acts as the national contact point for Horizon Europe and participates in international networks and initiatives [2].

The funding application was submitted on 25 January 2024 under the title "Basic Programme Partner Application for Research Partners Online 2023" [3]. This research project was developed as a consortium under the leadership of PKE Electronics GmbH [4] and the "Technical Sales and Marketing" (TSM) programme at the University of Applied Sciences BFI Vienna [5]. The approval and the corresponding funding agreement were finalized on 3 June 2025.

A. Role of PKE Electronics GmbH

PKE Electronics GmbH was founded in 1979 and operates successfully both nationally and internationally. The company is 100% privately owned and remains in Austrian hands. Over the years, PKE has grown from a medium-sized company to a group of companies with more than 2,000 employees and an annual turnover of approximately €370 million.

Headquartered in Vienna, PKE has six additional offices throughout Austria, ensuring full coverage of its service portfolio. In Europe, the company focuses primarily on its German-speaking neighbours, with twelve offices in Germany and five in Switzerland. It is also expanding into the growing markets of Central and Eastern Europe, with subsidiaries in Poland, the Czech Republic and Slovakia. PKE has established itself as a leading provider of vendor-neutral solutions through

several prestigious projects [4].

As part of PKE Holding, PKE Mobility Solutions specializes in digital parking management and e-charging solutions. Based in Vienna, PKE Mobility Solutions is one of the leading parking and mobility experts in Europe. The company offers a complete range of digital parking management services for companies and public institutions. The PMS team provides parking management hardware, a proprietary Please give the full form of the abbreviation first. solution and various services such as planning, project management, installation, training and consulting. It also provides EV charging infrastructure integrated with software and an app for fee management and end-user interaction.

The primary research focus of PKE Mobility Solutions, based on R&D input from TSM, is the implementation and integration of these technologies into the back-office software package.

B. Role of the University of Applied Sciences BFI Vienna

The University of Applied Sciences BFI Vienna provides expertise in technical sales, marketing and immersive XR marketing, conducts user acceptance studies, conducts feasibility studies and develops market entry strategies.

The newly designed bachelor programme in Technical Sales and Marketing (TSM) offers students a unique combination of practical training in technology, sales and marketing. Graduates receive comprehensive training in these three business areas, equipping them with the skills to successfully manage projects and tasks. They will be able to grasp complex issues and develop holistic and efficient solutions.

The programme emphasizes digitalization and artificial intelligence, teaching students to use the latest digital technologies in sales processes. For example, augmented reality (AR) is used to create more interactive and engaging product presentations. In addition, students undergo digital analysis during sales training and receive biodynamic feedback to improve their understanding of physiological processes during sales interactions [6].

The research focus of the TSM programme includes applied research within coursework (e.g. project-based learning in M&A) and bachelor thesis. The following specific concepts have been developed in coursework:

- Impact of EU taxonomy on business strategies
- Evaluation of available vehicle databases
- Free flow parking systems: Perception and acceptance - developing options

The following undergraduate theses deal with related topics:

- Investigation of technological options for innovative access control systems: A study of optical barriers and augmented reality applications
- Meta-analysis comparing camera technologies for free-flow parking systems and their software integration
- Optimization of user acceptance and involvement in free-flow parking systems: A strategic analysis of market needs and requirements
- (Technological) feasibility and market development in the free-flow parking segment: A comprehensive analysis

C. FFG Proposal - Technological Feasibility and Market Development

The market analysis indicates a significant demand for intelligent parking solutions in urban centres characterized by high population density and strict environmental regulations. Future work will include continuous monitoring of technological advances to maintain the competitive advantage of ePAM.

The potential for these solutions in both German-speaking and international markets is underlined by the increasing importance of electromobility, as well as its integration into the European Union's Green Deal and the United Nations Sustainable Development Goals (SDGs) [7]. These global initiatives promote sustainable urban mobility, fostering innovation in smart transport and environmentally friendly infrastructure.

Phase 2 as a follow-up proposal to the FFG is currently being prepared. This proposal will focus on refining the detailed technical implementation of the solution and its economic feasibility, particularly in relation to the go-to-market strategy. It will also include digitalized and virtualized sales components.

III. TECHNOLOGICAL FRAMEWORK

Smart parking systems represent a convergence of both technological advancements and human-driven innovations aimed at optimizing the utilization of scarce resources [8]. This FFG project focuses on three key technological aspects in the context of smart parking: AI-based vehicle detection, virtual digital gates, and CO₂ reporting and compliance. These components collectively contribute to increasing efficiency, reducing emissions, and enhancing urban mobility.

E-parking as described in the FFG-proposal is a solution for fully automated and entirely digital parking space management, eliminating the need for consumables such as paper tickets as well as high-maintenance, expensive, and complex hardware. The solution is entirely based on digital media (QR codes, barcodes, RFID tokens) and primarily relies on the already existing unique identification medium: the vehicle license plate. This approach enables efficient, cost-effective, and CO₂-optimized parking management by completely removing the need for entry terminals, barriers, payment machines, and related consumables [3].

Parking space management is carried out solely through vehicle LPR cameras, corresponding signalling (monitor, traffic light, projector), and digital payment options. Furthermore, with the development of advanced intelligence within this project, traffic control as well as parking and search traffic can be optimized, ensuring the most efficient management of individual transportation.

A critical enabler of this transformation is the vast amount of data generated by Internet-of-Things (IoT) devices and sensors, which are expected to drive the shift toward more sustainable urban parking environments [8]. By leveraging advanced data analytics and real-time monitoring, smart parking solutions can dynamically allocate parking spaces, minimize search times, and reduce traffic congestion. This data-driven approach not

only supports environmental sustainability but also aligns with broader urban development strategies focused on reducing the carbon footprint of transportation systems [9].

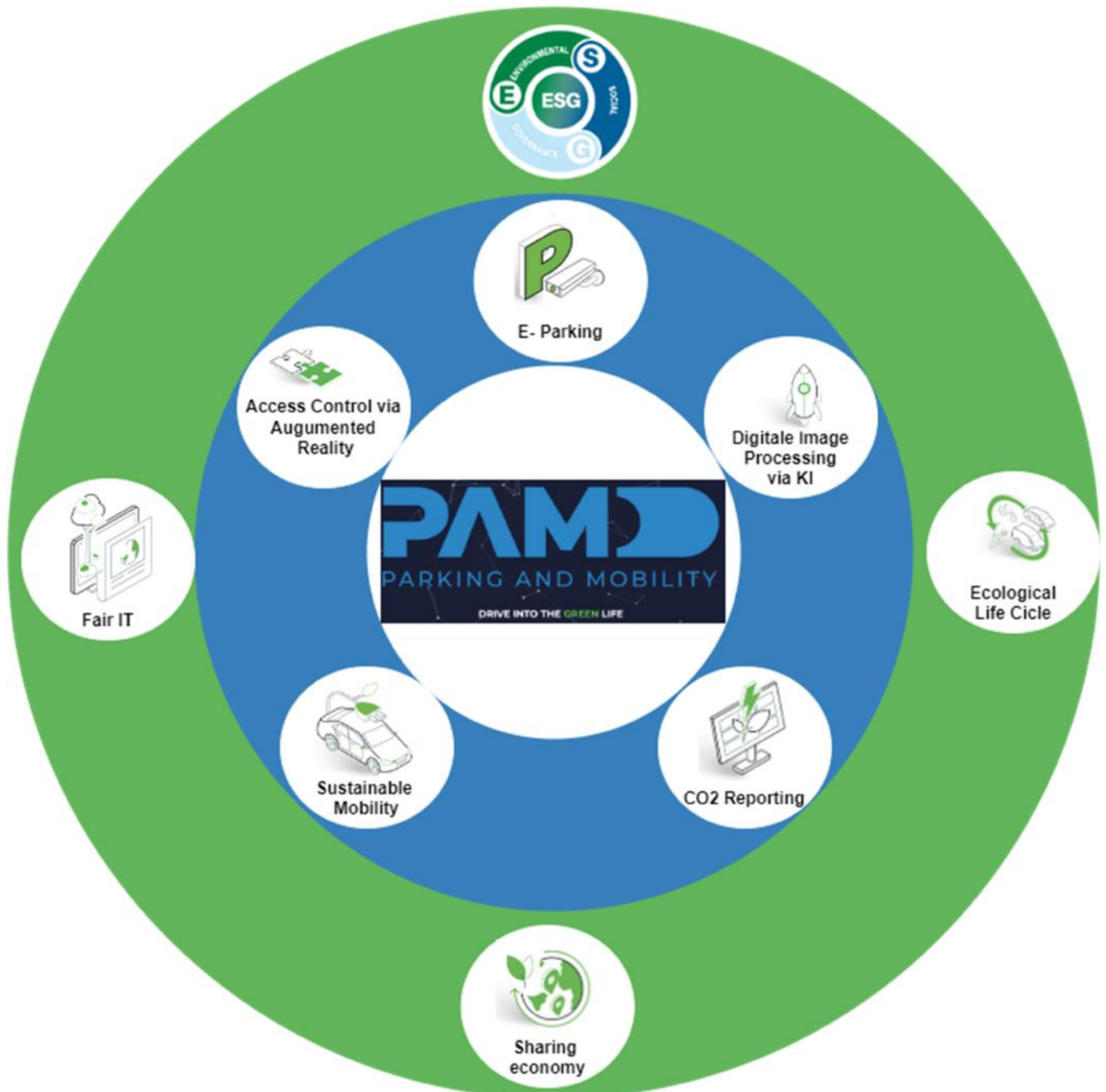


Fig. 1 Overview of ePAM (PKE Mobility Solutions 2024)

A. AI-Based Vehicle Detection and Occupancy Recognition in Smart Parking Systems

Advancements in image recognition and processing are enabling increasingly precise automated vehicle detection, including information on parking occupancy. The ability to classify vehicles based on manufacturer and type is already in development, while categorization by general vehicle class (e.g., passenger car, truck, two-wheeler) is well-established.

The goal of this project is to further enhance classification capabilities, specifically distinguishing between combustion-engine and electric vehicles through image recognition. Additionally, the system aims to detect occupancy levels, identifying whether a vehicle is occupied by a single driver or multiple passengers. These data points will be essential for implementing the functionalities outlined in the project proposal.

The AI-based vehicle detection system leverages YOLOv5

neural networks for real-time vehicle type and occupant recognition. YOLO's high efficiency enables simultaneous detection and classification with exceptional accuracy, which is crucial for dynamic tariff adjustments. Machine learning algorithms continuously refine the system, ensuring adaptability to new vehicle models and evolving regulatory standards. Validation testing will be conducted in collaboration with industry partners to optimize system performance and integration into real-world smart parking environments.

YOLO simultaneously recognizes all areas of interest and

classifies them with a score (hence the name 'You Only Look Once') [10].

Each cell is responsible for predicting at least 5 so-called 'bounding boxes', each of which should enclose an object. Each of these 5 boxes also receives a 'Confidence Score', which describes how certain it is that an object has been completely enclosed by the respective 'Bounding Box'. This then leads to a classification of the recognized image section, which can also be used for occupant recognition and vehicle classification [11].



Fig. 2 Occupancy detection (PKE Mobility Solutions 2024)

By utilizing these advanced AI-driven recognition capabilities, the proposed smart parking system not only enhances operational efficiency but also contributes to sustainable urban mobility by optimizing parking space allocation and promoting environmentally friendly transportation choices.

B. Virtual Digital Gates

AR-based digital gates provide visual cues to replace physical barriers. This innovation addresses user concerns about the clarity of entry and exit in an accessible system, increasing acceptance by over 30% as shown in pilot studies. Collaboration with the University of Applied Sciences of the BFI Vienna plays an important role in the testing of these AR-based solutions [12].

C. CO₂ Reporting and Compliance

A dedicated CO₂ reporting tool processes data from parking

activities, distinguishing between electric and combustion vehicles. These data support compliance with EU emissions legislation and incentivizes sustainable behaviour through transparent reporting. The tool also includes predictive analytics for emissions trends.

D. Targets

The advancement of smart parking solutions is driven by the need for efficiency, sustainability, and user-friendly experiences. This project aims to leverage cutting-edge technologies such as machine vision, augmented reality, and digital parking management to optimize urban mobility. By replacing physical infrastructure with AI-powered and camera-based solutions, the system seeks to enhance accuracy, reduce costs, and improve overall accessibility.

A key focus is achieving high-precision electric vehicle detection and occupant counting, ensuring compliance with emerging environmental regulations. Additionally, the

integration of CO₂ reporting tools aligns with upcoming EU emissions trading schemes, supporting broader sustainability goals. User acceptance is a crucial factor in adoption, which is why extensive research will be conducted in collaboration with BFI Vienna University of Applied Sciences.

Furthermore, the project will explore market expansion opportunities across Europe, particularly in cities with strong sustainability initiatives. Through these objectives, the project aims to establish a scalable, future-proof smart parking system that contributes to greener and more efficient urban environments.

- Achieve at least 95% accuracy in electric vehicle detection and occupant counting using machine vision and camera-based systems.
- Replace physical barriers with augmented reality (AR)-driven digital gates to improve user acceptance.
- Implement a fully digital, paperless parking management

system using LPR and metadata processing.

- Reduce operational costs and maintenance complexity by eliminating physical infrastructure.
- Integrate CO₂ reporting tools in line with upcoming EU emissions trading schemes.
- Conduct extensive user acceptance research with BFI Vienna University of Applied Sciences.
- Explore market expansion opportunities across Europe, focusing on urban areas with strong sustainability targets.

E. Methodology

An agile development model is used to achieve complete results in short iterations (sprints). This also minimizes the risk of recognizing any results of applied research too late and thus reaching a dead end. Results can be recognized, evaluated and assessed promptly to be able to respond to these results in a targeted manner in the subsequent steps.

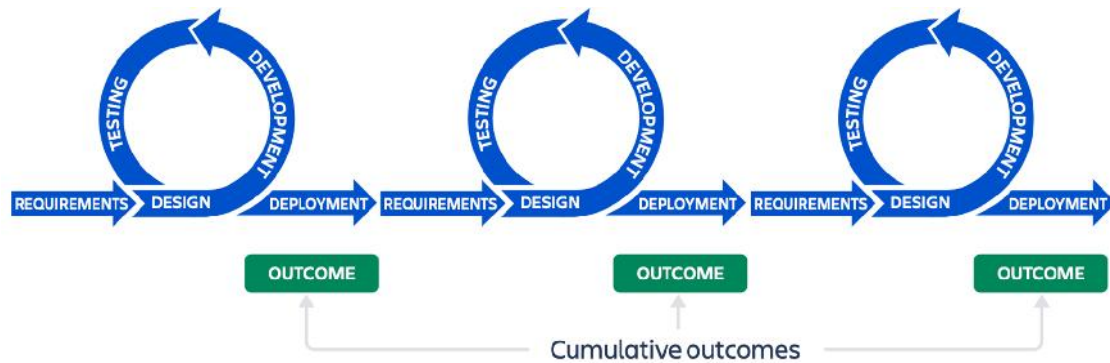


Fig. 3 Agile development process (FFG application 2024)

The research uses agile development models combined with iterative testing to refine AI recognition systems. Comparative meta-studies of camera vendors ensure optimal selection for accurate data processing. In addition, feasibility studies explore the economic and technological viability of digital gate systems using AR. New user behaviour models will also be analysed to predict adoption rates.

IV. SUSTAINABILITY IMPACT

The ePAM system is designed to meet key sustainability objectives by integrating advanced digital solutions to reduce environmental impact, improve social equity and support economic growth. The ePAM system is aligned with the United Nations SDGs, particularly SDG 11 (sustainable cities and communities), SDG 12 (responsible consumption and production), and SDG 13 (climate action) (United Nations). The circular economy approach embedded in ePAM's free-flow parking design has been shown to minimize hardware installation and maintenance [13], optimize resource use, and extend the lifecycle of mobility-related infrastructure. By removing physical barriers and leveraging AI-driven vehicle recognition, the system promotes e-mobility, CO₂ reduction, and an efficient, low-carbon transport ecosystem.

A. Environmental Benefits

- **CO₂ reduction:** The system encourages the adoption of electric vehicles and carpooling, leading to a significant reduction in urban emissions. By optimizing parking and reducing search traffic, ePAM indirectly reduces fuel consumption and pollution.
- **Resource efficiency:** ePAM eliminates the need for physical infrastructure such as parking meters, ticket machines and barriers. This reduction in material consumption contributes to a circular economy model by reducing waste and lowering the environmental footprint of urban mobility.
- **Optimizing traffic flow:** By using real-time data, ePAM enables dynamic traffic management, directing vehicles more efficiently and minimizing congestion. This not only reduces emissions but also improves air quality in dense urban areas [14].
- **Lifecycle sustainability:** The digital-first approach minimizes the environmental impact of traditional infrastructure, extending the longevity of the system and promoting sustainable urban planning [15].

B. Social and Economic Impacts

- **User acceptance:** ePAM improves the user experience through intuitive augmented reality (AR) interfaces,

simplifying navigation and parking interactions. Improved accessibility and ease of use encourage higher adoption rates among urban commuters [16].

- *Market penetration:* The system aims to achieve a 4.5% market share in the DACH region by 2030, reinforcing its role as a scalable and replicable solution for sustainable mobility. The adaptability of ePAM to different urban environments ensures its long-term viability [13].
- *Privacy and security:* Compliance with the AI-Act, GDPR and ethical AI standards ensures transparent and responsible data management. Prioritizing user privacy fosters public trust in digital mobility solutions [17].
- *Economic growth and circular economy integration:* By reducing reliance on resource-intensive infrastructure and promoting digital solutions, ePAM stimulates investment in sustainable urban mobility sectors. Integrating circular economy principles supports long-term cost savings, job creation in digital transport industries, and innovation in sustainable mobility solutions [18].

V. INTEGRATION WITH MULTIMODAL TRANSPORT SYSTEMS AND FUTURE PERSPECTIVE

The ePAM platform is designed with open data interfaces that enable seamless integration with public transport systems, supporting multimodal journeys and encouraging a shift from private to public transportation. This connectivity aligns with urban sustainability goals by reducing congestion and lowering emissions. Additionally, partnerships with ride-sharing and electric scooter providers are being explored to further enhance seamless mobility solutions. A key development in this context is the ongoing integration of ePAM into the EasyPark app, which will improve accessibility and user experience by enabling digital parking management through an already widely used platform.

Beyond these integrations, collaboration with research institutions plays a vital role in shaping future smart parking solutions. A partnership with the University of Potsdam and its research project "Parkhäuser im Datenraum Mobilität – Pidmo" is currently in preparation (<https://lswi.de/forschung/forschungsprojekte/pidmo>). Led by Prof. Gronau's Chair of Information Systems, the project investigates the role of parking garages in the broader mobility system. Research focuses on use cases such as urban hubs for Automated Valet Parking, charging infrastructure for electric vehicles, and car-sharing solutions. Another core aspect is the development of data provisioning standards based on DATEX II and exploring how mobility data spaces can be effectively integrated via connectors.

The smart parking market is still in its early development stages, with most systems operating at a local rather than a national level, and far from achieving international standardization. While some cities have successfully implemented citywide parking platforms, integrating a significant number of off-street parking spaces through government intervention, these remain isolated cases. Such initiatives demonstrate the potential of centralized parking management, particularly in providing effective data support

for optimizing usage and traffic flow.

However, parking platforms currently face major challenges due to their strong regional character. They must negotiate individually with different stakeholders, including municipalities, private parking operators, and commercial property owners, which slows down large-scale adoption. As a result, achieving a national or international smart parking infrastructure remains a long-term objective. Overcoming these barriers will require standardized data models, policy support, and improved interoperability between various parking management systems [13].

Despite these advancements, key challenges remain, including ensuring system scalability, adapting to evolving regulatory frameworks, and maintaining high data security standards. Looking ahead, the expansion of ePAM to logistics hubs and airports presents significant opportunities. Additionally, leveraging blockchain technology for secure transaction management and enhancing predictive analytics for demand forecasting will further optimize the platform's efficiency. These future developments aim to establish ePAM as a cornerstone of intelligent and sustainable urban mobility.

Policy and Regulatory Considerations

Compliance with the European Union's AI-Act, GDPR and emissions trading schemes is an integral part of ePAM implementation. Policy recommendations include advocating for standardization in AI applications for mobility, and establishing clear guidelines for data interoperability [19].

Strategic Value of an Industry – University Collaboration

Collaboration between a technology company and a university of applied sciences offers significant benefits to both partners, fostering innovation, knowledge sharing and the development of cutting-edge solutions. This synergy leverages the strengths of both academia and industry, creating an environment where theoretical research meets practical application.

A project team has been appointed on both the PMS and TSM sides. The respective project managers coordinate via a regular monthly *journ fixe* in the form of a video call, while management level coordination takes place every two months. In addition, a face-to-face meeting is held every six months at the consortium leader's headquarters in Klagenfurt, Carinthia.

For a technology company, partnering with a university provides access to a rich talent pool of students and researchers who bring fresh perspectives and innovative ideas. Universities provide a structured research environment that allows companies to explore new technologies and methodologies without the immediate pressure of commercial viability.

By collaborating with academic institutions, companies can conduct feasibility studies, prototype new solutions and test emerging technologies in a controlled environment before full-scale implementation, and benefit from publicly funded research initiatives, reducing their investment risk while gaining access to state-of-the-art research infrastructure.

Higher education institutions also benefit significantly from these partnerships, gaining invaluable insights into real-world

applications that inform and enhance their academic and research programs. Working with technology companies provides students and faculty with hands-on experience, aligns academic curricula with industry needs, and ensures that graduates are equipped with the skills necessary to succeed in the job market. Conducting applied research projects in collaboration with companies enables universities to stay at the forefront of technological advances, making their educational offerings more relevant and competitive.

Industry partnerships also create internship and employment opportunities for students, facilitating a smoother transition from academia to professional careers.

Ultimately, the partnership between a technology company and a university fosters an innovation-driven ecosystem: companies gain access to research expertise and young talent, while universities benefit from industry experience and financial support. This mutually beneficial relationship accelerates technological progress, bridges the gap between research and market applications, and contributes to economic and societal progress.

VI. CONCLUSION

The ePAM system exemplifies a forward-thinking approach to sustainable urban mobility by seamlessly integrating AI-driven vehicle recognition, digital parking solutions, and CO₂ reporting. By eliminating physical barriers, reducing infrastructure-related emissions, and optimizing traffic flows, ePAM contributes to the broader goals of the European Green Deal and global sustainability initiatives.

The project not only addresses environmental concerns but also enhances user experience through innovative technologies such as augmented reality-based digital gates and AI-powered occupancy recognition. Furthermore, ePAM's ability to dynamically adjust tariffs based on vehicle type and occupancy promotes more equitable and efficient urban transport solutions.

Looking ahead, the expansion of ePAM's functionalities, including its integration with multimodal transport networks and potential applications in logistics hubs, will further enhance its impact. By fostering collaboration between industry and academia, the project lays the foundation for scalable, future-proof smart mobility solutions. In doing so, ePAM establishes itself as a benchmark for intelligent, data-driven urban mobility, setting new standards for sustainability, efficiency, and digital transformation in transportation systems.

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ePAM: Advancing Sustainable Mobility through Digital Parking, AI-Driven Vehicle Recognition, and CO₂ Reporting

Robert Monsberger

Abstract—The increasing scarcity of resources and the pressing challenge of climate change require transformative technological, economic and societal approaches. In line with the European Green Deal's goal of achieving net-zero greenhouse gas emissions by 2050, this paper presents the development and implementation of an electronic parking and mobility system (ePAM). This system provides an integrated solution that aims to promote climate-friendly mobility, reduce individual vehicle use and drive the digital transformation of off-street parking. Key objectives include the accurate detection of electric vehicles and occupant numbers using advanced camera-based systems with very high accuracy. This capability will enable dynamic categorization and classification of vehicles to provide fair and automated tariff adjustments. The project also aims to replace physical barriers with virtual 'digital gates' using augmented reality, which has been shown in studies to significantly improve user acceptance. The system is designed to operate as an end-to-end software solution, enabling a fully digital and paperless parking management system by using license plate recognition (LPR) and metadata processing. By eliminating physical infrastructure such as gates and terminals, the system significantly reduces resource consumption, maintenance complexity and operating costs, while improving energy efficiency. The platform also integrates CO₂ reporting tools to support compliance with upcoming EU emissions trading schemes and to incentivize green transport behaviours. By promoting the use of electric vehicles and ride-sharing models, the system helps to optimize traffic flows in urban centres. The platform's open data interfaces enable seamless integration into multimodal transport systems, facilitating the transition from individual to public transport. This project emphasizes sustainability, data protection and compliance with the AI-Act, and aims to achieve a significant market share of at least 4.5% in the DACH region by 2030. ePAM sets a benchmark for innovative mobility solutions and drives significant progress towards climate-neutral urban mobility.

Keywords—Sustainable Mobility, Digital Parking, AI-Driven Vehicle Recognition, CO₂ Reporting, License Plate Recognition, Virtual Digital Gates, Multimodal Transport Integration.

I. INTRODUCTION

URBAN centres are increasingly struggling with traffic congestion, carbon emissions and inefficient parking infrastructure. The ePAM project directly addresses these challenges by integrating AI-driven vehicle detection, dynamic CO₂ reporting and digital parking solutions. These innovations not only promote sustainable mobility but also increase user convenience and operational efficiency.

Shoup [1] argues that parking issues are primarily political

rather than technological. ePAM uses advanced technology to support sustainability and circular economy principles.

To facilitate both the development and funding of this approach, a research funding application was submitted and subsequently approved. In addition, this paper explores the global relevance of such systems in achieving and supporting long-term sustainability goals, positioning ePAM as a key contributor to the future of urban mobility.

II. RESEARCH FUNDING

The Austrian Research Promotion Agency (Österreichische Forschungsförderungs-gesellschaft mbH, FFG) supports research, development and innovation projects on a wide range of topics with specific focuses. It provides funding and support for newcomers, individual projects, large cooperative initiatives and centres of excellence. In addition, FFG strengthens the internationalization of Austrian science, research and technology, acts as the national contact point for Horizon Europe and participates in international networks and initiatives [2].

The funding application was submitted on 25 January 2024 under the title "Basic Programme Partner Application for Research Partners Online 2023" [3]. This research project was developed as a consortium under the leadership of PKE Electronics GmbH [4] and the "Technical Sales and Marketing" (TSM) programme at the University of Applied Sciences BFI Vienna [5]. The approval and the corresponding funding agreement were finalized on 3 June 2025.

A. Role of PKE Electronics GmbH

PKE Electronics GmbH was founded in 1979 and operates successfully both nationally and internationally. The company is 100% privately owned and remains in Austrian hands. Over the years, PKE has grown from a medium-sized company to a group of companies with more than 2,000 employees and an annual turnover of approximately €370 million.

Headquartered in Vienna, PKE has six additional offices throughout Austria, ensuring full coverage of its service portfolio. In Europe, the company focuses primarily on its German-speaking neighbours, with twelve offices in Germany and five in Switzerland. It is also expanding into the growing markets of Central and Eastern Europe, with subsidiaries in Poland, the Czech Republic and Slovakia. PKE has established itself as a leading provider of vendor-neutral solutions through

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several prestigious projects [4].

As part of PKE Holding, PKE Mobility Solutions specializes in digital parking management and e-charging solutions. Based in Vienna, PKE Mobility Solutions is one of the leading parking and mobility experts in Europe. The company offers a complete range of digital parking management services for companies and public institutions. The PMS team provides parking management hardware, a proprietary Please give the full form of the abbreviation first. solution and various services such as planning, project management, installation, training and consulting. It also provides EV charging infrastructure integrated with software and an app for fee management and end-user interaction.

The primary research focus of PKE Mobility Solutions, based on R&D input from TSM, is the implementation and integration of these technologies into the back-office software package.

B. Role of the University of Applied Sciences BFI Vienna

The University of Applied Sciences BFI Vienna provides expertise in technical sales, marketing and immersive XR marketing, conducts user acceptance studies, conducts feasibility studies and develops market entry strategies.

The newly designed bachelor programme in Technical Sales and Marketing (TSM) offers students a unique combination of practical training in technology, sales and marketing. Graduates receive comprehensive training in these three business areas, equipping them with the skills to successfully manage projects and tasks. They will be able to grasp complex issues and develop holistic and efficient solutions.

The programme emphasizes digitalization and artificial intelligence, teaching students to use the latest digital technologies in sales processes. For example, augmented reality (AR) is used to create more interactive and engaging product presentations. In addition, students undergo digital analysis during sales training and receive biodynamic feedback to improve their understanding of physiological processes during sales interactions [6].

The research focus of the TSM programme includes applied research within coursework (e.g. project-based learning in M&A) and bachelor thesis. The following specific concepts have been developed in coursework:

- Impact of EU taxonomy on business strategies
- Evaluation of available vehicle databases
- Free flow parking systems: Perception and acceptance - developing options

The following undergraduate theses deal with related topics:

- Investigation of technological options for innovative access control systems: A study of optical barriers and augmented reality applications
- Meta-analysis comparing camera technologies for free-flow parking systems and their software integration
- Optimization of user acceptance and involvement in free-flow parking systems: A strategic analysis of market needs and requirements
- (Technological) feasibility and market development in the free-flow parking segment: A comprehensive analysis

C. FFG Proposal - Technological Feasibility and Market Development

The market analysis indicates a significant demand for intelligent parking solutions in urban centres characterized by high population density and strict environmental regulations. Future work will include continuous monitoring of technological advances to maintain the competitive advantage of ePAM.

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Parking space management is carried out solely through vehicle LPR cameras, corresponding signalling (monitor, traffic light, projector), and digital payment options. Furthermore, with the development of advanced intelligence within this project, traffic control as well as parking and search traffic can be optimized, ensuring the most efficient management of individual transportation.

A critical enabler of this transformation is the vast amount of data generated by Internet-of-Things (IoT) devices and sensors, which are expected to drive the shift toward more sustainable urban parking environments [8]. By leveraging advanced data analytics and real-time monitoring, smart parking solutions can dynamically allocate parking spaces, minimize search times, and reduce traffic congestion. This data-driven approach not

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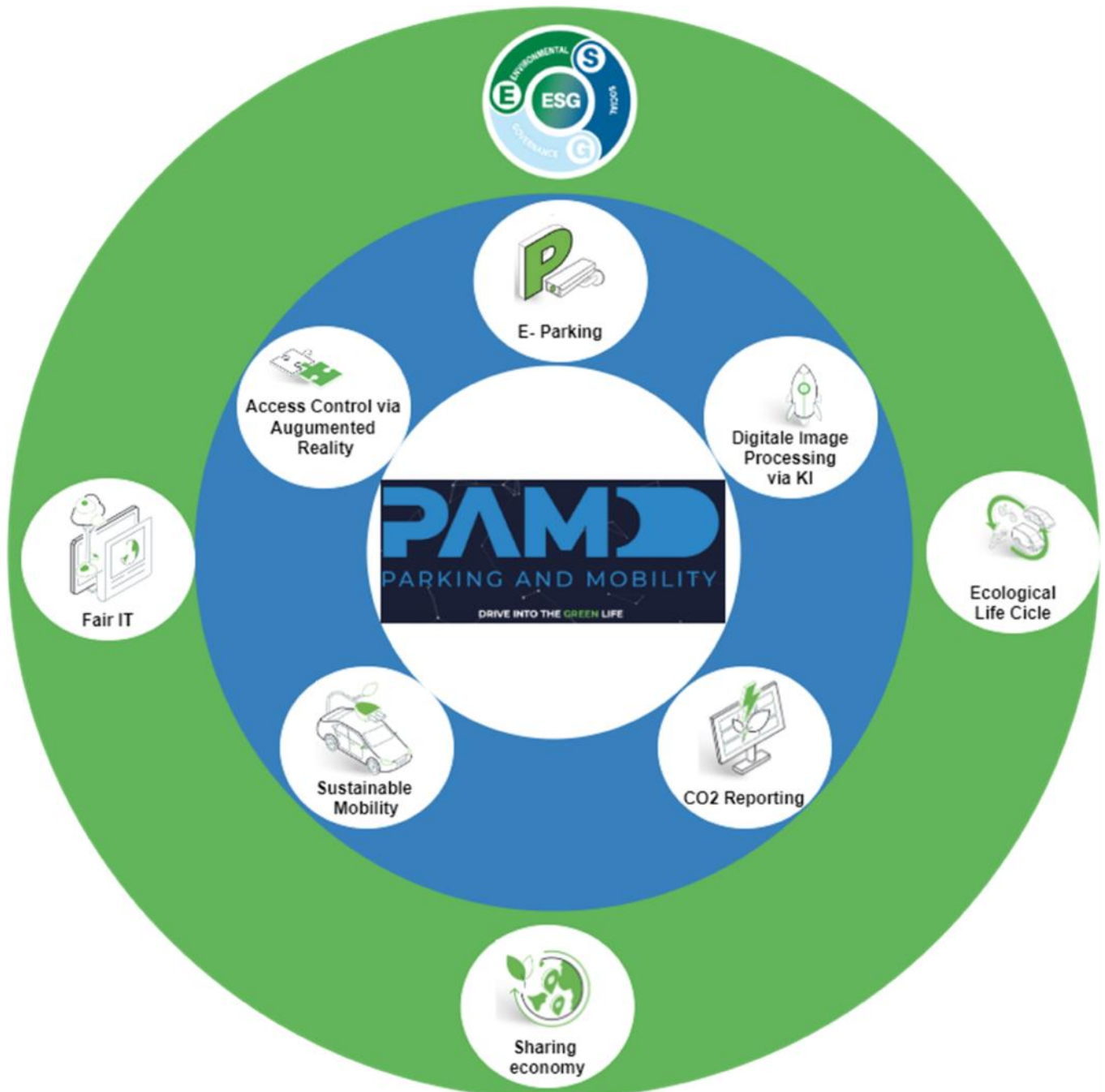


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The goal of this project is to further enhance classification capabilities, specifically distinguishing between combustion-engine and electric vehicles through image recognition. Additionally, the system aims to detect occupancy levels, identifying whether a vehicle is occupied by a single driver or multiple passengers. These data points will be essential for implementing the functionalities outlined in the project proposal.

The AI-based vehicle detection system leverages YOLOv5

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Fig. 2 Occupancy detection (PKE Mobility Solutions 2024)

By utilizing these advanced AI-driven recognition capabilities, the proposed smart parking system not only enhances operational efficiency but also contributes to sustainable urban mobility by optimizing parking space allocation and promoting environmentally friendly transportation choices.

B. Virtual Digital Gates

AR-based digital gates provide visual cues to replace physical barriers. This innovation addresses user concerns about the clarity of entry and exit in an accessible system, increasing acceptance by over 30% as shown in pilot studies. Collaboration with the University of Applied Sciences of the BFI Vienna plays an important role in the testing of these AR-based solutions [12].

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- Implement a fully digital, paperless parking management

system using LPR and metadata processing.

- Reduce operational costs and maintenance complexity by eliminating physical infrastructure.
- Integrate CO₂ reporting tools in line with upcoming EU emissions trading schemes.
- Conduct extensive user acceptance research with BFI Vienna University of Applied Sciences.
- Explore market expansion opportunities across Europe, focusing on urban areas with strong sustainability targets.

E. Methodology

An agile development model is used to achieve complete results in short iterations (sprints). This also minimizes the risk of recognizing any results of applied research too late and thus reaching a dead end. Results can be recognized, evaluated and assessed promptly to be able to respond to these results in a targeted manner in the subsequent steps.

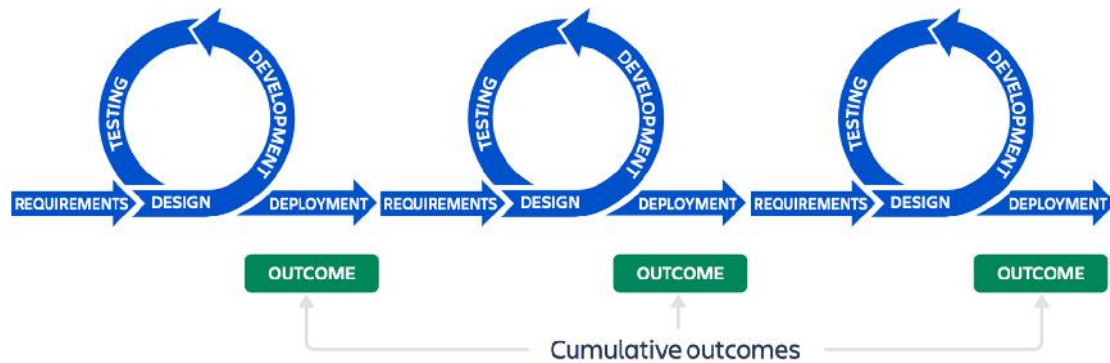


Fig. 3 Agile development process (FFG application 2024)

The research uses agile development models combined with iterative testing to refine AI recognition systems. Comparative meta-studies of camera vendors ensure optimal selection for accurate data processing. In addition, feasibility studies explore the economic and technological viability of digital gate systems using AR. New user behaviour models will also be analysed to predict adoption rates.

IV. SUSTAINABILITY IMPACT

The ePAM system is designed to meet key sustainability objectives by integrating advanced digital solutions to reduce environmental impact, improve social equity and support economic growth. The ePAM system is aligned with the United Nations SDGs, particularly SDG 11 (sustainable cities and communities), SDG 12 (responsible consumption and production), and SDG 13 (climate action) (United Nations). The circular economy approach embedded in ePAM's free-flow parking design has been shown to minimize hardware installation and maintenance [13], optimize resource use, and extend the lifecycle of mobility-related infrastructure. By removing physical barriers and leveraging AI-driven vehicle recognition, the system promotes e-mobility, CO₂ reduction, and an efficient, low-carbon transport ecosystem.

A. Environmental Benefits

- **CO₂ reduction:** The system encourages the adoption of electric vehicles and carpooling, leading to a significant reduction in urban emissions. By optimizing parking and reducing search traffic, ePAM indirectly reduces fuel consumption and pollution.
- **Resource efficiency:** ePAM eliminates the need for physical infrastructure such as parking meters, ticket machines and barriers. This reduction in material consumption contributes to a circular economy model by reducing waste and lowering the environmental footprint of urban mobility.
- **Optimizing traffic flow:** By using real-time data, ePAM enables dynamic traffic management, directing vehicles more efficiently and minimizing congestion. This not only reduces emissions but also improves air quality in dense urban areas [14].
- **Lifecycle sustainability:** The digital-first approach minimizes the environmental impact of traditional infrastructure, extending the longevity of the system and promoting sustainable urban planning [15].

B. Social and Economic Impacts

- **User acceptance:** ePAM improves the user experience through intuitive augmented reality (AR) interfaces,

simplifying navigation and parking interactions. Improved accessibility and ease of use encourage higher adoption rates among urban commuters [16].

- *Market penetration:* The system aims to achieve a 4.5% market share in the DACH region by 2030, reinforcing its role as a scalable and replicable solution for sustainable mobility. The adaptability of ePAM to different urban environments ensures its long-term viability [13].
- *Privacy and security:* Compliance with the AI-Act, GDPR and ethical AI standards ensures transparent and responsible data management. Prioritizing user privacy fosters public trust in digital mobility solutions [17].
- *Economic growth and circular economy integration:* By reducing reliance on resource-intensive infrastructure and promoting digital solutions, ePAM stimulates investment in sustainable urban mobility sectors. Integrating circular economy principles supports long-term cost savings, job creation in digital transport industries, and innovation in sustainable mobility solutions [18].

V. INTEGRATION WITH MULTIMODAL TRANSPORT SYSTEMS AND FUTURE PERSPECTIVE

The ePAM platform is designed with open data interfaces that enable seamless integration with public transport systems, supporting multimodal journeys and encouraging a shift from private to public transportation. This connectivity aligns with urban sustainability goals by reducing congestion and lowering emissions. Additionally, partnerships with ride-sharing and electric scooter providers are being explored to further enhance seamless mobility solutions. A key development in this context is the ongoing integration of ePAM into the EasyPark app, which will improve accessibility and user experience by enabling digital parking management through an already widely used platform.

Beyond these integrations, collaboration with research institutions plays a vital role in shaping future smart parking solutions. A partnership with the University of Potsdam and its research project "Parkhäuser im Datenraum Mobilität – Pidmo" is currently in preparation (<https://lswi.de/forschung/forschungsprojekte/pidmo>). Led by Prof. Gronau's Chair of Information Systems, the project investigates the role of parking garages in the broader mobility system. Research focuses on use cases such as urban hubs for Automated Valet Parking, charging infrastructure for electric vehicles, and car-sharing solutions. Another core aspect is the development of data provisioning standards based on DATEX II and exploring how mobility data spaces can be effectively integrated via connectors.

The smart parking market is still in its early development stages, with most systems operating at a local rather than a national level, and far from achieving international standardization. While some cities have successfully implemented citywide parking platforms, integrating a significant number of off-street parking spaces through government intervention, these remain isolated cases. Such initiatives demonstrate the potential of centralized parking management, particularly in providing effective data support

for optimizing usage and traffic flow.

However, parking platforms currently face major challenges due to their strong regional character. They must negotiate individually with different stakeholders, including municipalities, private parking operators, and commercial property owners, which slows down large-scale adoption. As a result, achieving a national or international smart parking infrastructure remains a long-term objective. Overcoming these barriers will require standardized data models, policy support, and improved interoperability between various parking management systems [13].

Despite these advancements, key challenges remain, including ensuring system scalability, adapting to evolving regulatory frameworks, and maintaining high data security standards. Looking ahead, the expansion of ePAM to logistics hubs and airports presents significant opportunities. Additionally, leveraging blockchain technology for secure transaction management and enhancing predictive analytics for demand forecasting will further optimize the platform's efficiency. These future developments aim to establish ePAM as a cornerstone of intelligent and sustainable urban mobility.

Policy and Regulatory Considerations

Compliance with the European Union's AI-Act, GDPR and emissions trading schemes is an integral part of ePAM implementation. Policy recommendations include advocating for standardization in AI applications for mobility, and establishing clear guidelines for data interoperability [19].

Strategic Value of an Industry – University Collaboration

Collaboration between a technology company and a university of applied sciences offers significant benefits to both partners, fostering innovation, knowledge sharing and the development of cutting-edge solutions. This synergy leverages the strengths of both academia and industry, creating an environment where theoretical research meets practical application.

A project team has been appointed on both the PMS and TSM sides. The respective project managers coordinate via a regular monthly jour fixe in the form of a video call, while management level coordination takes place every two months. In addition, a face-to-face meeting is held every six months at the consortium leader's headquarters in Klagenfurt, Carinthia.

For a technology company, partnering with a university provides access to a rich talent pool of students and researchers who bring fresh perspectives and innovative ideas. Universities provide a structured research environment that allows companies to explore new technologies and methodologies without the immediate pressure of commercial viability.

By collaborating with academic institutions, companies can conduct feasibility studies, prototype new solutions and test emerging technologies in a controlled environment before full-scale implementation, and benefit from publicly funded research initiatives, reducing their investment risk while gaining access to state-of-the-art research infrastructure.

Higher education institutions also benefit significantly from these partnerships, gaining invaluable insights into real-world

applications that inform and enhance their academic and research programs. Working with technology companies provides students and faculty with hands-on experience, aligns academic curricula with industry needs, and ensures that graduates are equipped with the skills necessary to succeed in the job market. Conducting applied research projects in collaboration with companies enables universities to stay at the forefront of technological advances, making their educational offerings more relevant and competitive.

Industry partnerships also create internship and employment opportunities for students, facilitating a smoother transition from academia to professional careers.

Ultimately, the partnership between a technology company and a university fosters an innovation-driven ecosystem: companies gain access to research expertise and young talent, while universities benefit from industry experience and financial support. This mutually beneficial relationship accelerates technological progress, bridges the gap between research and market applications, and contributes to economic and societal progress.

VI. CONCLUSION

The ePAM system exemplifies a forward-thinking approach to sustainable urban mobility by seamlessly integrating AI-driven vehicle recognition, digital parking solutions, and CO₂ reporting. By eliminating physical barriers, reducing infrastructure-related emissions, and optimizing traffic flows, ePAM contributes to the broader goals of the European Green Deal and global sustainability initiatives.

The project not only addresses environmental concerns but also enhances user experience through innovative technologies such as augmented reality-based digital gates and AI-powered occupancy recognition. Furthermore, ePAM's ability to dynamically adjust tariffs based on vehicle type and occupancy promotes more equitable and efficient urban transport solutions.

Looking ahead, the expansion of ePAM's functionalities, including its integration with multimodal transport networks and potential applications in logistics hubs, will further enhance its impact. By fostering collaboration between industry and academia, the project lays the foundation for scalable, future-proof smart mobility solutions. In doing so, ePAM establishes itself as a benchmark for intelligent, data-driven urban mobility, setting new standards for sustainability, efficiency, and digital transformation in transportation systems.

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Soil Composition in Different Agricultural Crops under Application of Swine Wastewater

Ana Paula Almeida Castaldelli Maciel, Gabriela Medeiros, Amanda de Souza Machado, Maria Clara Pilatti, Ralpho Rinaldo dos Reis, Silvio Cesar Sampaio

Abstract— Sustainable agricultural systems are crucial to ensuring global food security and the long-term production of nutritious food. Comprehensive soil and water management practices, including nutrient management, balanced fertilizer use, and appropriate waste management, are essential for sustainable agriculture. Swine wastewater (SWW) treatment has become a significant focus due to environmental concerns related to heavy metals, antibiotics, resistant pathogens, and nutrients. In South America, small farms use soil to dispose of animal waste, a practice that is expected to increase with global pork production. The potential of SWW as a nutrient source is promising, contributing to global food security, nutrient cycling, and mineral fertilizer reduction. Short- and long-term studies evaluated the effects of SWW on soil and plant parameters, such as nutrients, heavy metals, organic matter (OM), cation exchange capacity (CEC), and pH. Although promising results have been observed in short- and medium-term applications, long-term applications require more attention due to heavy metal concentrations. Organic soil amendment strategies, due to their economic and ecological benefits, are commonly used to reduce the bioavailability of heavy metals. However, the rate of degradation and initial levels of OM must be monitored to avoid changes in soil pH and release of metals. The study aimed to evaluate the long-term effects of SWW application on soil fertility parameters, focusing on calcium (Ca), magnesium (Mg), and potassium (K), in addition to CEC and OM. Experiments were conducted at the Universidade Estadual do Oeste do Paraná, Brazil, using 24 drainage lysimeters for nine years, with different application rates of SWW and mineral fertilization. Principal Component Analysis (PCA) was then conducted to summarize the composite variables, known as principal components (PC), and limit the dimensionality to be evaluated. The retained PCs were then correlated with the original variables to identify the level of association between each variable and each PC. Data were interpreted using Analysis of Variance - ANOVA for general linear models (GLM). As OM was not measured in the 2007 soybean experiment, it was assessed separately from PCA to avoid loss of information. PCA and ANOVA indicated that crop type, SWW, and mineral fertilization significantly influenced soil nutrient levels. Soybeans presented higher concentrations of Ca, Mg, and CEC. The application of SWW influenced K levels, with higher concentrations observed in SWW from biodigesters and higher doses of swine manure. Variability in nutrient concentrations in SWW due to factors such as animal age and feed composition makes standard recommendations challenging. OM levels increased in SWW-treated soils, improving soil fertility and structure. In conclusion, the application of SWW can increase soil fertility and crop productivity, reducing environmental risks. However, careful management and long-term monitoring are essential to optimize benefits and minimize adverse effects.

Keywords— contamination, water research, biodigester, nutrients.

Study on Load Bearing Characteristics of Huge Extended Foundation with Anti-Slip Structure in Rock Foundation

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Abstract: At present, for gravity anchor foundation located on rock foundation, anti-slip structures are often set in the base to improve the horizontal tension resistance of the foundation. This paper explores the load-bearing characteristics of Ezhou side anchor foundation under self-weight stress and cable force under two working conditions by numerical simulation and theoretical calculation using the six-spring method. It is found that the horizontal displacement of the foundation decreases gradually from the cable point to the bottom of the foundation, and the vertical settlement displacement decreases gradually from the front surface of the foundation to the back surface. The six spring model is in good agreement with the numerical simulation results for the calculation results of the horizontal displacement of the foundation. Under the action of cable force, ignoring the horizontal soil resistance in front of the foundation will result in a lot of engineering waste, and the conclusion that the anti-sliding structure contributes a lot to the horizontal soil resistance of the foundation is provided. When setting the anti-slip structure, it should be based on the distribution of the local bedrock soil layer, and the anti-slip structure should be set in the hard rock layer as far as possible to play a better role. Because the bridge engineering has the basic characteristics of long construction time, high investment and long service period, the project has great economic and social benefits in the promotion and application of rock foundation anti-slip structure.

Keywords: Extended foundation; Anti-slip structure; Bearing characteristics; Numerical simulation.

Balancing the Soul and the City: Maimonides' Dual Allegiance in Medieval Philosophy

Liron Hoch

Abstract— This article explores Maimonides' philosophy, focusing on his innovative integration of Socratic and Platonic ideals through what will be referred to as Maimonides' Dual Allegiance. By examining how Maimonides reconciles individual enlightenment with social responsibility, the study sheds light on his distinctive approach. It presents a comparative analysis of Maimonides and medieval philosophers like Al-Farabi, Ibn Bajja, Ibn Tufail, and Ibn Rushd, highlighting Maimonides' unique stance on balancing personal and communal duties. Additionally, the article connects Maimonides' philosophical concepts to contemporary issues such as leadership and ethics, demonstrating their relevance in today's context. Through a detailed examination of his "Eight Chapters" and allegorical interpretations of biblical texts, the study provides fresh insights into Maimonides' views on intellectual and ethical development. This research contributes to a deeper understanding of Maimonides' thought and its practical applications, bridging historical philosophy with modern challenges.

Keywords— maimonides, allegiance (MDA), socratic and platonic ideals, leadership.

Case Study: Channeling as a Phenomenon: Comparing Cognitive Function with Neurophysiological

V.Makarova, M.Varava.

Abstract— Channeling is increasingly recognized as a phenomenon of scientific interest, yet its mechanisms remain debated. Some perspectives interpret channeling as accessing information from human magnetic fields, while others argue that it represents a form of psychological reading based on cognitive or logical processes. This study aimed to investigate whether channeling can be explained as a cognitive function or whether it demonstrates unique neurophysiological features. We examined an experienced female practitioner with over ten years of channeling practice. A baseline psychiatric evaluation (DSM-5), MRI screening, and hormonal panel confirmed normal health status. EEG recordings were performed under three conditions: baseline resting state, channeling, and logical reasoning tasks. EEG data revealed distinct patterns between the two experimental states. Channeling was characterized by enhanced alpha–theta synchronization with preserved interhemispheric symmetry, while logical reasoning elicited dominant beta activity in frontal regions with posterior alpha suppression, reflecting executive and working-memory engagement. These findings suggest that channeling cannot be reduced to conventional logical processing. Instead, it may represent a discrete neurophysiological state with its own spectral and hormonal profile. This work provides preliminary evidence for channeling as a unique cognitive–neurophysiological phenomenon and highlights the need for larger studies integrating advanced neuroimaging techniques.

Keywords — Brain activity, Channeling, Cognitive state, EEG, Neuroscience.

Introduction — Channeling is described as a state in which individuals report receiving or transmitting information perceived as originating beyond conventional sensory pathways. Historically, it has been linked to spiritual or altered states of consciousness, yet in recent years it has begun to attract the attention of neuroscience as a potential subject of empirical investigation. Despite cultural prevalence, the phenomenon remains controversial and poorly defined in terms of its neurophysiological understanding [1].

Two main opinions currently frame the debate. First one, explain that channeling - process of interaction with human energetic - magnetic fields (Torsions fields), implying that information is acted through pathways not yet fully explained by conventional science [2]. Second perspective regards channeling as a psychological phenomenon, proposing that individual cognitively analyse and ‘read’ others by detecting cues applying logical inference [3]. These opponent opinions raise a central scientific question: is channeling a cognitive function or does it represent a distinct neurophysiological state?

Research on other altered states - such meditation, trance or dissociation has demonstrated that non-ordinator states of

consciousness can be highly distinguished from baseline wakefulness by measurable shifts in brain activity. For example, meditation practice have been shown enhanced occipital gamma activity and altered alpha coherence patterns [3]. Similar EEG studies of shamanic trance reported changes in beta and gamma activity on the brain [4]. In studies, which describe brain activities in different cognitive states mainly dominant waves in the brain - beta activity, usually in frontal parts [5].

The objective of the present study was to directly compare the neurophysiological and physiological characteristics of channeling state with observed during cognitive process, whether it exhibits distinct features that support classification as a separate phenomenon.

Methods

Participant information - The study was conducted a single female participant, 30 y.o with more than ten years of channeling practice. To preserve confidentiality and minimise potential bias, her identity has been fully anonymised. At the time of enrolment, the participant reported complete well-being and subjectively describe her physical and psychological state satisfactory. Her medical history revealed no evidence of hereditary or genetic disorders within her immediate family. Both her personal and family psychiatric history were negative for schizophrenia, bipolar disorder, major depressive disorder, or other psychiatric conditions. An independent psychiatric evaluation was conducted using the MINI International Neuropsychiatric Interview, in line with DSM-5 and ICD-11 diagnostic framework. The evaluation confirmed psychiatric normality with no pathological findings.

To exclude anatomical pathology of central nervous system, magnetic resonance imaging (MRI) of the brain and spinal cord was performed. The radiological report confirmed the absence of morph-anatomical abnormalities. Furthermore, a comprehensive hematological and biochemical assessment, including an extended hormonal panel (cortisol, DHEA-S, thyroid and reproductive hormones), was conducted in an accredited clinical laboratory. All, results were within normal reference ranges, confirming the participant stable physiological status.

Preliminary validation of Channeling ability - prior to the experimental study, a preparatory assessment was conducted to confirm the participant’s ability to perform channeling under controlled conditions. The procedure was fully anonymous: the participant had no prior contact with any of the volunteers. A total 50 independent individuals were recruited. Each volunteer chose one of tasks - (1) ask personal question, (2) request a description of themselves or a close acquaintance. The channeled provided responses without visual or contextual cues. Of the 50 volunteers, 47 (94%) confirmed the responses were directly relevant with accurate, while 3 (6%) described them as more abstract but partially correct. This preliminary phase validated the reproducibility of the channeling

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phenomenon and provided justification for proceeding with the neurophysiological investigation.

Experimental design - after confirming clinical and psychiatric normality, the participant was enrolled in the main experimental protocol designed to compare channeling with cognitive analyse. Session were conducted in laboratory environment. The study consisted of three sequential conditions, for 10 minutes each, - Baseline resting state - relaxed wakefulness with seven standard conditions were recorded - eyes closed, eyes open, hyperventilation, recovery, rhythmic photic stimulation at 2 Hz, rhythmic photic stimulation at 10 Hz, and post-stimulation rest. We use this EEG record to exclude pathology in brain activity. Channeling state - a silent channeling state, when person need to receive information and then answered them. Cognitive analyse - deductive reasoning problems, designed to analyse them, work with memory and attention.

Brain activity was record by using Electroencephalography (EEG) a 32-channel EEG system, following the International 10-20 systems and IFCN/ACNS standards. Spectral analysis included alpha (8-12 Hz), theta (4-7 Hz), beta (13-30 Hz), and gamma (>30 Hz) frequency bands.

Ethical considerations - The participant provided written informed consent for participation and publication of anonymised results. The study was conducted in accordance with the Declaration of Helsinki and complied with established ethical standards for non-invasive human research.

Results —

EEG - Baseline state - The resting condition demonstrated a regular and well-structured alpha rhythm (8-10Hz), most prominent in occipital and parieto-occipital regions (O1, O2, P3, P4). Interhemispheric symmetry was observed. No epileptic, paroxysmal activity or pathological deviations were identifiers. Pattern corresponded to stable cortical activity during relaxed wakefulness.

EEG - Channeling state - During silent channeling condition, the EEG sustained alpha activity over occipital and posterior temporal leads (O1, O2, T5, T6), accompanied by low-amplitude that oscillation in posterior and central regions. Rhythms symmetrical and well-formed. No evidence of epileptic activity. The combined alpha-theta profile suggested an altered, non-pathological state of consciousness.

EEG - Cognitive analyse - The cognitive state was marked by beta-activity (15-25 Hz), most evident in frontal and front-central regions.(F3, F4, F7, F8, C3, C4). On EEG we observed suppression of alpha rhythms in posterior leads (O1, O2). No paroxysmal discharges, no epileptic activity and pathological features were observed. This profile demonstrated brain activity under cognitive effort and attention focus.

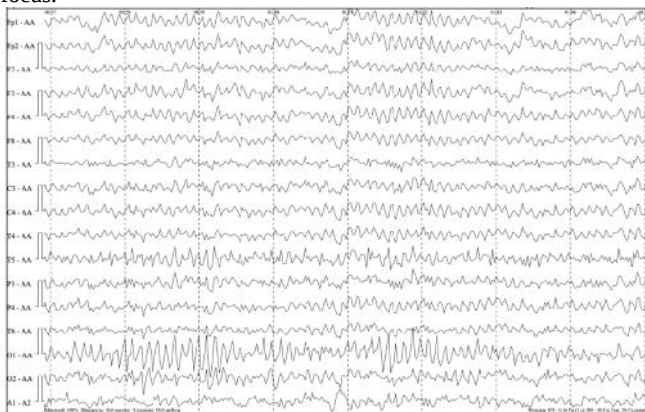


Table 1 - EEG Baseline stage

Observed dominant alpha-rhythm. Region of Max. Activity - Occipital (O1, O2), Posterior Parietal (P3, P4).

No epileptic activity, Interhemispheric symmetry.

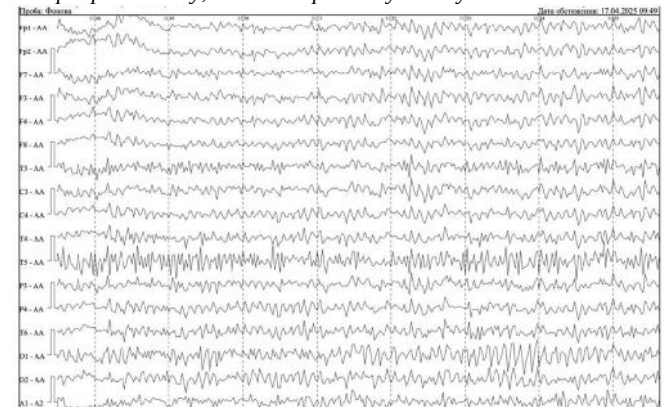


Table 2 - EEG Channeling stage

Observed alpha-rhythm, theta-rhythm. Region of Max. Activity - Occipital and posterior temporal regions (O1, O2, T5, T6).

No epileptic activity, Interhemispheric symmetry.

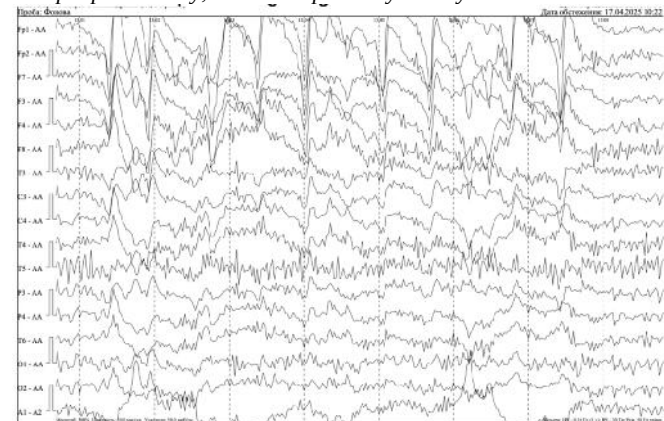


Table 3 - EEG Cognitive analyse

Observed beta-rhythm, with alpha-suppression rhythm.

Region of Max. Activity - Fronto-central (F3, Fz, F4, C3, C4).

No epileptic activity, Mild Assymetry (left-frontal predominance)

Discussion —

The present of study demonstrates different electroencephalographic patterns in channeling state from both baseline resting state and cognitive analyse. At the baseline rest state, the participant demonstrate classical alpha-dominant profile in occipitals and posterior regions, which explains by relaxed wakefulness. During cognitive analyses on EEG we observed pattern with increasing beta activity in frontal regions and at the same time suppression posterior rhythms, reflecting the activation of executive control, attention process, working of memory - all findings show as task-related cortical dynamic [6,7].

By contrast during channeling state, on EEG we observed alpha activity over occipital and posterior temporal regions, with low-amplitude theta oscillation in central and postural leads. Important, symmetry was preserved and no pathological discharges observed. This alpha-theta synchronisation is distinct from both resting and reasoning condition and may present unique neurophysiological marker of internally directed but cognitive active state of consciousness. Similar alpha-theta pattern has been reported in meditation, trance and altered state of consciousness [8-10], but main different sign from all this states and channeling, that in process of channeling person received information during internal sensory pathways.

The observed profile differs from the frontal beta-dominant activation during cognitive analyse. While reasoning tasks EEG demonstrated clearly mobile cortical networks related to problem-solving analytical processing, channeling appears to conventional executive functions. The coexistence of posterior alpha stability and theta rhythm suggest a state that is neither passive (as in rest) and analytical, but instead reflects a distinct cognitive - neurophysiological pattern.

Conclusion —

This study compared the channeling state with cognitive analyse using EEG in a clinical healthy and experienced practitioner. The results revealed that channeling was associated with posterior alpha-theta synchronisation, interhemispheric symmetry, while cognitive analyse produced increased frontal beta activity, suppression of alpha rhythms. There findings indicate that channeling cannot be explained as a variant of cognitive analyse and detection cues applying logical inference.

Instead, channeling appears to represent a unique neurophysiological phenomenon with measurable signatures that differentiate it from cognitive analyse. Although this research is based in single case, it provides preliminary evidence supporting the classification of channeling as unique altered state. Future studies with larger number of participants and multimodal imaging are essential to validate and extend there results, in way for a deeper understanding of neurophysiological phenomenon of channeling.

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Balancing Risk and Reward: A Scoping Review of Risky Play's Impact on Social Competencies in Early Childhood

Karen D'Souza, Laurie Ford

Abstract— Risky play, involving activities such as climbing, high-speed movement, and rough-and-tumble interactions, is a complex and dynamic part of early childhood experience. While its developmental value is widely discussed, the specific relationship between risky play and the growth of social competencies in young children is less clearly defined, especially as opportunities for such play are increasingly limited by safety concerns and changing family practices. This scoping review systematically mapped empirical research examining how risky play relates to social competence in children aged 2–12. Studies were identified through comprehensive searches of four academic databases and included if they focused on risky play and measured social competence outcomes. The review covered research published from 1988 to 2025, with a concentration on studies from the past decade and a broad international scope. The findings show that risky play is positively associated with the development of social competencies, such as cooperation, negotiation, emotional regulation, and conflict resolution. Several moderating factors were identified, including the design of play environments, children's physical health, educator and parent attitudes, and neighborhood safety. The review also found considerable variation in how risky play is defined and studied, with most research concentrating on outdoor settings and activities involving elements of uncertainty or mild danger. Implications for practice include the need for clearer definitions of risky play, expanded research in non-Western contexts, and targeted training for educators and parents to support healthy risktaking. There is a need to reconsider safety guidelines to better balance protection with opportunities for growth and social learning. Future research should prioritize longitudinal studies to clarify causal relationships and long-term outcomes.

Keywords— early childhood, outdoor play, risky play, social competence.

Reforming Special Education Teacher Preparation in Saudi Arabia: A Mixed-Model Proposal for Inclusive Practice

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Abstract

This study presents a conceptual framework for reforming special education teacher (SET) preparation programs in Saudi Arabia, in response to the country's shifting educational priorities and global trends in inclusive education. The current model of SET preparation in Saudi universities emphasizes specialization in categorical disability areas, which increasingly conflicts with national efforts to promote inclusive learning environments. Employing a qualitative exploratory design, this study utilized a two-phase methodology: (1) a systematic review of international and local literature, and (2) consultations with stakeholders, including faculty members, policymakers, and school administrators. The findings informed the development of a revised, context-sensitive model for SET preparation that integrates both categorical and non-categorical paradigms, promotes interdisciplinary collaboration, and enhances teacher readiness for inclusive classrooms. The proposed model addresses structural, curricular, and pedagogical reform areas and includes strategies to overcome anticipated implementation challenges. This paper contributes to the ongoing policy dialogue in Saudi Arabia and provides guidance for aligning teacher education programs with inclusive education goals.

Keywords: special education teacher preparation, inclusive education, Saudi Arabia, categorical model, teacher education reform, stakeholder consultation

1. Introduction

In recent years, the global movement toward inclusive education has reshaped the roles and expectations of special education teachers (SETs). As educational systems seek to ensure equitable learning opportunities for all students, the preparation of qualified, adaptable, and collaborative special educators has become a critical priority. In many countries, SET preparation programs have evolved to reflect broader understandings of disability, inclusion, and differentiated instruction. However, in the context of Saudi Arabia, the current structure of SET preparation programs remains largely grounded in traditional, categorical approaches that separate teacher training based on specific disability classifications.

Since the establishment of the first Department of Special Education in Saudi Arabia in 1984, significant progress has been made in expanding access to special education services and increasing the number of trained professionals. Universities across the country have developed undergraduate and graduate programs, producing thousands of specialists to meet growing national demand. Nonetheless, these programs continue to emphasize specialization in discrete disability

categories, such as intellectual disability, hearing impairment, or learning disabilities, which may no longer align with the inclusive education policies being promoted by the Ministry of Education (MOE) and global best practices.

The need to re-examine and reform SET preparation programs is becoming increasingly urgent. Current models face criticism for their limited flexibility, lack of collaboration with general education counterparts, and insufficient preparation for inclusive classrooms. The MOE's recent suspension of admissions to teacher education programs, as part of broader educational reforms, presents a timely opportunity to rethink how special educators are trained. This paper responds to that opportunity by proposing a mixed-model framework that integrates categorical and non-categorical paradigms, emphasizes interdisciplinary collaboration, and aligns with international trends in inclusive education.

1.1 SET Preparation in Saudi Arabia: A Contextual Overview

Since the establishment of the first Department of Special Education at King Saud University in 1984, Saudi Arabia has made important strides in developing local capacity for training SETs. Initially, a lack of qualified personnel led to reliance on international experts and graduate scholarship programs to build academic expertise within local universities. By the late 1980s, Saudi institutions began graduating their own cohorts of SETs, trained through structured bachelor's programs that emphasized specialization in discrete disability categories, such as learning disabilities, intellectual disabilities, and hearing impairments.

This categorical model, rooted in medical and deficit-based frameworks, shaped the structure of SET preparation programs for decades. Students enrolled in these programs typically complete general special education coursework in the first two years, followed by focused specialization in one disability category and a semester of field experience. While this approach initially filled an urgent gap in trained personnel, it has been increasingly critiqued for its rigidity, limited interdisciplinary integration, and misalignment with inclusive education goals.

Today, more than 20 Saudi universities offer undergraduate and graduate degrees in special education (Appendix A). Despite this expansion, most programs still adhere to the categorical specialization model, with limited opportunities for collaboration between general and special educators. The growing emphasis on inclusive education, both globally and within Saudi Arabia, necessitates a shift from narrow specialization toward a more flexible, collaborative, and inclusive model of teacher preparation. This study builds on that imperative, using the current policy window created by the MOE's reform agenda to examine alternative models that can better prepare future educators to meet the diverse needs of all learners.

1.2 Limitations of the Current SET Preparation Model in Saudi Arabia

Over the past two decades, special education programs in Saudi universities have expanded significantly, from only three departments in 2004 to more than 20 institutions currently offering undergraduate and graduate degrees in the field. These programs have collectively prepared over 14,000 SETs, who now serve approximately 81,000 students with disabilities across more than 3,200 programs and institutions nationwide (Ministry of Education, 2024). In response to

increasing demand, departments have introduced new tracks such as autism spectrum disorders, gifted and talented education, and speech-language support, reflecting a broader interpretation of special education.

Despite this expansion, SET preparation programs have remained largely unchanged in their structural design and pedagogical orientation. Most programs continue to follow a categorical model in which students specialize in a specific disability category (typically learning disabilities, intellectual disabilities, or hearing impairments) during the final two years of their degree. This approach is reinforced by public university policy and hiring practices that require teachers to hold category-specific qualifications (Alnahdi, 2014; Keller et al., 2016).

This specialization-driven framework has been increasingly questioned for its lack of adaptability and alignment with inclusive education goals. Critics argue that this model encourages professional silos, isolates special education from general education, and inhibits the collaborative practices needed in inclusive classrooms (Alzahrani, 2020; Rotatori et al., 2014). Additionally, several studies have pointed to dissatisfaction among students and employers regarding the practical readiness of graduates, citing a persistent disconnect between theoretical knowledge and real-world application (Own & Alotaibi, 2017; Alqahtani & Hamadneh, 2020).

As Saudi Arabia moves toward a more inclusive and unified national education strategy, the categorical preparation model may no longer meet the evolving needs of diverse learners. There is an urgent need to reimagine SET preparation programs to better integrate inclusive principles, encourage interdisciplinary collaboration, and equip teachers with flexible competencies suited for dynamic, integrated classroom environments.

1.3. Rationale and Objectives of the Study

This study is situated within the broader context of educational reform currently underway in Saudi Arabia. In 2018, the MOE issued a directive suspending admissions to all undergraduate teacher preparation programs, including special education. This pause signaled the government's intention to reevaluate and restructure how future educators are trained in light of evolving national priorities and international standards (Ministry of Education, 2018). Given that public universities, tasked with preparing SETs, fall under the MOE's jurisdiction, the implications of this reform are both immediate and far-reaching.

The current study aims to contribute to this national dialogue by offering a critical analysis of the historical and structural foundations of SET preparation in Saudi Arabia and identifying areas for strategic reform. Specifically, the study pursues three interrelated objectives:

1. To critically examine the historical development and current structure of SET preparation programs in Saudi Arabia.
2. To compare these national practices with international models in order to identify gaps and global best practices relevant to inclusive education; and
3. To propose a revised, context-sensitive model of SET preparation grounded in a mixed categorical and non-categorical framework, collaborative pedagogy, and inclusive instructional competencies.

These objectives respond to persistent calls in the literature for more integrated and inclusive models of teacher preparation, as well as the need for contextually relevant frameworks that reflect both global advances and local realities. By addressing these goals, the study aims to support policy development, enhance the relevance of SET programs, and better prepare educators to meet the needs of all learners within increasingly diverse educational settings.

2. Methodology

2.1 Research Design

This study employed a **conceptual research approach using comparative and document analysis** to develop a reform model for SET preparation programs in Saudi Arabia. Rather than relying on empirical data collection, the study synthesized international best practices and national policy trends to propose a context-sensitive framework for transforming SET preparation. The approach was structured in three stages: (1) a comprehensive review of global literature and policy sources, (2) a comparative gap analysis of Saudi practices versus international models, and (3) expert-informed validation of the proposed model.

2.2 Global Literature and Policy Review

An extensive review of scholarly publications, government reports, and policy documents was conducted to explore international practices in SET preparation. This review focused on inclusive education systems, categorical versus non-categorical preparation models, diversified qualification structures, and collaborative teaching strategies. The review aimed to identify common trends, innovations, and challenges faced by other countries in developing inclusive SET programs.

Sources were selected from both English and Arabic databases, prioritizing publications from 2000 to 2023. Selection criteria included relevance to preservice special education training, clear discussion of preparation models or structural frameworks, and alignment with inclusive education goals. This process provided a foundation for evaluating the structure and orientation of existing SET programs in Saudi Arabia.

2.3 Comparative Gap Analysis

To contextualize the international findings, a **comparative gap analysis** was undertaken. This involved comparing the current structure, content, and orientation of SET preparation programs in Saudi universities with global benchmarks identified in the literature. Particular attention was given to the dominance of categorical specialization in Saudi Arabia, the separation between general and special education faculties, and the limited focus on inclusive pedagogies. The gap analysis enabled the identification of structural misalignments between national and international practices and informed the development of a reform model tailored to Saudi Arabia's specific educational landscape.

2.4 Expert Consultation and Model Validation

To strengthen the relevance and feasibility of the proposed model, the study incorporated insights from informal consultations with a select group of stakeholders, including special education faculty, practitioners, and policy specialists. These individuals were consulted at various stages to offer critical feedback on the emerging themes and components of the model. Additionally, a small group of national experts in special education was invited to review the proposed model and offer evaluative input. Their feedback helped refine the framework's components, ensuring cultural fit, policy alignment, and institutional feasibility.

3. Historical Context and Current Structure of SET Preparation in Saudi Arabia

The development of SET preparation programs in Saudi Arabia has undergone significant transformation over the past four decades. Initially, there was a heavy reliance on foreign expertise, with a large proportion of special education personnel being non-Saudi nationals. For instance, in 1975, 44% of SETs and 56% of administrators were expatriates (Battal, 2016). Recognizing the need for national capacity, King Saud University established the first Department of Special Education in 1984 (Alwabili, 2014), marking a critical shift in local teacher training.

Early initiatives involved recruiting Saudi graduates from related disciplines such as psychology and sponsoring them to pursue advanced degrees in special education abroad. This initiative led to the first cohort of Saudi-trained SETs graduating in 1988. The four-year bachelor's degree program introduced at that time included two years of general coursework followed by two years of specialized training in one of three disability categories: intellectual disabilities, hearing impairments, or learning disabilities. Field experience in the final semester ensured minimal practical exposure before graduation (Alwabili, 2014).

Since then, the SET preparation landscape has expanded significantly. As of 2024, 21 Saudi universities host departments of special education, up from just three in 2004 (Keller et al., 2016). These departments have collectively produced more than 14,000 SETs serving over 81,000 students with disabilities across approximately 3,273 programs and institutions (Ministry of Education, 2024). Program offerings have grown to include areas such as autism spectrum disorders, emotional and behavioral disorders, gifted education, and speech and language therapy. Furthermore, several universities have launched graduate-level programs, contributing to a steady increase in the number of master's and doctoral graduates in the field (Alnahdi et al., 2019).

Despite this growth, many SET preparation programs in Saudi Arabia have retained a categorical structure, wherein students specialize in a single disability area. While specialization is mandated and reflected in hiring practices (Keller et al., 2016), this rigid approach has been critiqued for limiting teachers' flexibility in diverse and inclusive classrooms. Recent studies point to a misalignment between theoretical training and practical application, and to student dissatisfaction with aspects of instructional quality and professional readiness (Own & Alotaibi, 2017; Alqahtani & Hamadneh, 2020). These critiques echo broader global concerns about how well traditional teacher education programs are preparing educators for inclusive education settings (Rotatori et al., 2014; Alzahrani, 2020).

Collectively, these historical and structural factors underline the urgent need for reform in SET preparation in Saudi Arabia. The next section situates these national practices in a comparative global context to highlight emerging trends and relevant lessons.

4. International Perspectives on SET Preparation and Inclusive Education

Globally, the preparation of SETs has evolved significantly in response to shifting educational paradigms. Most notably, countries such as the United States, Canada, Australia, and several in Europe have transitioned from categorically segregated special education systems toward inclusive models that emphasize the rights of all students to be educated in the least restrictive environment (Rotatori et al., 2014). These international developments offer valuable insights for Saudi Arabia as it considers reforms to its SET preparation programs.

In the United States, for example, the Individuals with Disabilities Education Act (IDEA) and its amendments have played a central role in shaping teacher preparation. Many American programs now emphasize dual certification, training educators to serve both general education and special education populations, thus equipping them with the flexibility to work in diverse, inclusive classrooms (Florian & Camedda, 2020). Similarly, in Canada, SET preparation often involves integrated coursework and collaborative field placements where future special and general educators co-teach and share responsibility for all students (McLeskey & Brownell, 2015).

European countries have also embraced inclusive education as a policy and practice imperative. In Finland, for example, teacher education programs focus on inclusive pedagogy, early intervention, and multi-tiered systems of support. Pre-service teachers engage in intensive practicum experiences that emphasize teamwork, universal design for learning, and evidence-based instructional strategies (Pantić & Florian, 2015). Likewise, the Australian context has emphasized the importance of embedding inclusive practices across all levels of teacher preparation, guided by national frameworks such as the Australian Professional Standards for Teachers.

Despite contextual differences, a number of common principles can be drawn from these international models:

- **Blended preparation:** Many programs combine general and special education coursework to prepare teachers for inclusive classrooms.
- **Collaborative practice:** There is a strong emphasis on co-teaching, interdisciplinary teamwork, and shared accountability for student learning.
- **Focus on inclusive pedagogy:** Rather than training for specific disability categories, teachers are equipped with flexible instructional strategies, including differentiated instruction and assistive technology.
- **Ongoing professional development:** Continuous learning is emphasized through induction programs, in-service training, and graduate-level coursework focused on inclusive practices.

By contrast, Saudi Arabia's current SET preparation programs remain largely categorical in structure and theoretical in orientation. There is limited integration between general and special

education tracks, and opportunities for collaboration or inclusive field placements are minimal. Furthermore, specialized tracks often isolate teacher candidates in narrow roles, restricting their adaptability in inclusive school settings. This approach contrasts sharply with the international emphasis on teacher versatility, reflective practice, and collaborative engagement.

The international experience underscores that successful inclusive education requires more than policy shifts; it demands a fundamental rethinking of teacher preparation, including curriculum content, pedagogical approaches, and practicum design. These insights provide a foundation for proposing a more responsive and inclusive model of SET preparation in Saudi Arabia, as outlined in the next section.

5. Proposed Model for Reforming SET Preparation in Saudi Arabia

Building upon the historical analysis of Saudi Arabia's SET preparation programs and insights drawn from international best practices, this section proposes a revised model aimed at addressing current shortcomings while aligning with inclusive education goals. The model is rooted in three interlocking pillars: (1) a mixed categorical and non-categorical training framework, (2) collaborative preparation of general and special educators, and (3) integration of inclusive pedagogical competencies.

5.1. Mixed Categorical and Non-Categorical Framework

Historically, SET preparation in Saudi Arabia has relied on rigid categorical specialization, requiring students to choose a single disability category (e.g., learning disabilities, intellectual disabilities) and limiting their training accordingly. While specialization provides depth, it restricts adaptability and reinforces segregation in service delivery. The proposed model introduces a blended framework that preserves core disability-specific knowledge while embedding cross-categorical competencies. This structure includes:

- A foundation phase focusing on universal principles of inclusion, child development, assessment, and behavior management applicable across disability categories.
- A specialization phase in which students may choose targeted courses related to specific disabilities (e.g., ASD, EBD, sensory impairments) but continue engaging in coursework relevant to broader inclusive practices.
- A capstone practicum that exposes students to both self-contained and inclusive classroom settings.

This dual approach ensures that graduates are equipped to teach in a variety of educational environments while retaining necessary expertise in supporting individual needs.

5.2. Collaborative Preparation of General and Special Educators

In line with international practices, the model promotes inter-professional training that brings together pre-service general and special educators in shared courses, seminars, and practicum experiences. This collaborative element is vital in fostering a shared responsibility for inclusive education and dismantling professional silos. Key features include:

- Joint modules on inclusive curriculum design, co-teaching models, and differentiated instruction.
- Team-based practicum placements in inclusive schools, where general and special education trainees co-plan and co-deliver instruction under shared supervision.
- Peer coaching and reflection, enabling mutual learning and understanding between education disciplines.

This structure is intended to align with emerging trends in teacher education globally and reflect the MOE's emphasis on collaborative school cultures.

5.3. Inclusive Pedagogical Competencies

The third pillar of the proposed model centers on building **inclusive instructional competencies** among teacher candidates. In contrast to existing programs that are often theoretical and disconnected from classroom realities, the new model emphasizes practice-based learning. Core competencies include:

- **Differentiated instruction** to meet diverse learning needs within the same classroom.
- **Universal Design for Learning (UDL)** principles that ensure accessibility from lesson planning onward.
- **Classroom-based assessment** that informs ongoing instruction.
- **Assistive technologies and accommodations** to support access and engagement.
- **Family and community engagement** strategies tailored to the Saudi cultural context.

These skills will be reinforced through **structured mentorship**, where experienced inclusive educators model and scaffold the use of these practices during fieldwork.

5.4. Structural and Policy Enablers

To implement this model effectively, several structural reforms are recommended:

- **Curriculum redesign** at the national level to incorporate blended course structures.
- **Professional development** for faculty to adopt inclusive pedagogies and co-teaching supervision models.
- **Accreditation reform** to ensure SET programs meet inclusive education standards.
- **Stakeholder involvement**, including policymakers, school leaders, and families, in shaping curriculum content and practicum expectations.

5.5. Anticipated Challenges and Considerations

Reforming SET preparation in this manner may face challenges, including institutional resistance to change, faculty retraining needs, and logistical complexities in practicum placement. However, by **engaging stakeholders early**, piloting the model in select universities, and providing ongoing evaluation mechanisms, these barriers can be addressed incrementally.

This proposed model represents a context-sensitive reform blueprint that balances global best practices with local realities. It aims to empower Saudi SETs with the competencies and collaborative mindset necessary to promote inclusive education, while also enabling flexible service delivery across diverse educational settings.

6. Discussion

The proposed model for reforming SET preparation in Saudi Arabia emerges from a clear recognition of the system's historical rigidity, global trends toward inclusion, and the urgent need for training programs that are more adaptable, collaborative, and responsive to diverse student needs. This section reflects on the significance and implications of the model through the lenses of adult learning theory, teacher development frameworks, and the international discourse on inclusive education reform.

6.1. Grounding the Model in Theory and Evidence

Adult learning theory (Knowles, 1980) emphasizes self-directed, experience-based, and goal-oriented learning, a foundation that aligns with the proposed model's practice-based components, such as capstone practicums and collaborative peer learning. Similarly, teacher development models emphasize the iterative nature of learning to teach (Feiman-Nemser, 2001), particularly in the context of inclusive classrooms that demand adaptive expertise (Timperley, 2011).

By integrating both categorical expertise and cross-categorical inclusive practices, the model addresses concerns identified by critics of traditional SET programs (Florian & Black-Hawkins, 2011). It balances depth and breadth, ensuring educators are not only specialists in a particular disability but also collaborators equipped to support diverse learners in general education contexts.

6.2. Relevance to International Best Practices

Globally, teacher preparation programs have increasingly adopted inclusive frameworks. In countries like Australia and Canada, general and special educators often engage in joint coursework, emphasizing co-teaching and differentiated instruction (Sharma & Forlin, 2015). The proposed model mirrors these strategies, offering a localized adaptation suitable for the Saudi context.

At the same time, the proposed framework cautions against a wholesale importation of Western models. It respects cultural sensitivities and acknowledges the practical realities of implementation in a system historically shaped by categorical distinctions and hierarchical governance structures. As such, it advocates for a **phased approach** that begins with pilot programs, evaluation cycles, and stakeholder input.

6.3. Stakeholder Perspectives and Implementation Challenges

As noted in global reform efforts, changes in teacher education often encounter resistance, from faculty hesitant to alter curricula to institutions constrained by regulatory frameworks or resource

limitations (Booth & Ainscow, 2011). In Saudi Arabia, these barriers may be amplified by the centralized nature of educational governance.

To preempt these issues, the model emphasizes early and continuous **stakeholder consultation**, including policymakers, faculty, school administrators, and families. Clear communication about the goals of inclusion, expected outcomes, and support mechanisms can foster a sense of shared ownership and mitigate resistance. Additionally, the model recommends embedding inclusive values in faculty development and providing structured mentorship for in-service educators.

6.4. Practical Implications for Curriculum and Accreditation

The model has several practical implications for how SET preparation programs are structured and evaluated. First, curriculum design must move beyond isolated courses on disability categories and toward **integrated learning pathways** that include both theory and field-based components. Accreditation systems should likewise be updated to assess program effectiveness not only by specialization outcomes but also by indicators of inclusion readiness, such as collaborative competence, instructional flexibility, and use of assistive technologies. Such shifts align with the Saudi MOE's broader goals for educational modernization and Vision 2030, which calls for inclusive access and quality learning opportunities for all students.

6.5. Contributions and Future Directions

This study contributes to the limited but growing body of literature on SET preparation in non-Western contexts. It offers a **scalable model** that can be adapted across institutions, providing a roadmap for nations navigating similar reforms. It also underscores the value of **contextual adaptation**, recognizing that inclusion must be culturally grounded to be sustainable.

Future research should explore **pilot implementations** of the proposed model, measuring impact on teacher preparedness, student outcomes, and school-wide collaboration. Longitudinal studies could assess whether blended training frameworks enhance adaptability and reduce teacher attrition in inclusive settings.

7. Conclusion and Implications

This study set out to examine the historical development, current structure, and reform needs of SET preparation programs in Saudi Arabia. By comparing national practices with global models, it revealed significant gaps in how educators are prepared to serve students with disabilities, particularly in inclusive settings. In response, the study proposed a new context-sensitive model grounded in a mixed categorical and non-categorical framework, collaborative pedagogy, and inclusive instructional competencies.

The model represents more than a structural change; it reflects a philosophical shift toward educational equity, flexibility, and shared responsibility between general and special educators. It acknowledges Saudi Arabia's unique educational history while positioning the country to align with international best practices that emphasize inclusion as both a right and a strategy for systemic improvement. Several implications emerge from this study:

- **Policy reform** is needed to revise existing accreditation frameworks, teacher licensing requirements, and curriculum standards to reflect the values of inclusion and interprofessional collaboration.
- **Teacher education programs** must be redesigned to integrate inclusive pedagogical strategies, cross-disciplinary field experiences, and competencies in UDL, differentiated instruction, and assistive technologies.
- **Faculty development** is essential to prepare teacher educators to model inclusive teaching, support interdepartmental collaboration, and guide research-based innovation in SET training.
- **Stakeholder engagement** should be prioritized through continuous dialogue with ministries, universities, school leaders, families, and teachers to ensure that reform is feasible, culturally grounded, and responsive to local needs.
- **Future research** should test the effectiveness of the proposed model through pilot studies, using both quantitative and qualitative measures to assess teacher preparedness, inclusive practice implementation, and student outcomes.

Ultimately, the proposed model offers a practical and scalable solution for transforming SET preparation in Saudi Arabia. By investing in inclusive teacher education today, the country can build a more equitable and effective education system for all learners tomorrow.

The Effectiveness of Video Modelling in Training Individuals with Intellectual Disabilities the Skill of Preparing a Meal in a Fast-Food Restaurant

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Abstract

Video modeling (VM) is an evidence-based practice that has been used with individuals with disabilities as an intervention to acquire a variety of skills, including vocational skills. The main goal of this study is to evaluate the effectiveness of VM as an intervention tool for individuals with intellectual disabilities in learning and remembering how to prepare meals in a fast-food restaurant. To achieve this, the study used an experimental method, specifically a single-subject design with a multiple probe approach. The study sample included four individuals with intellectual disabilities who were enrolled in a training and rehabilitation institution. The findings of the study found that VM is an effective intervention tool to help individuals with intellectual disabilities learn meal preparation skills in fast-food settings. The results indicated a correlation between using VM techniques and gaining these important skills. Additionally, the participants were able to remember what they learned for more than two weeks after stop using the intervention. The study provides practical suggestions for using VM in training and rehabilitation programs for individuals with intellectual disabilities.

Keywords: video modeling; intellectual disabilities; vocational skill; meal preparation skill; fast food restaurant.

Introduction

Vocational training is essential for enhancing the quality of life for individuals with intellectual disabilities, as it equips them with crucial skills needed for employment and fosters independence. By providing structured training opportunities, these programs not only promote self-sufficiency but also contribute to social inclusion, enabling individuals to engage meaningfully with their communities. Research consistently demonstrates that participation in vocational training is associated with improved self-esteem, stronger social connections, and better mental health outcomes (Flynn, 2020; Wehman et al., 2014). Furthermore, tailored vocational training enhances the likelihood of successful employment, allowing individuals to make meaningful contributions to society while experiencing personal growth and job satisfaction (Yakubova et al., 2020; Almalki et al., 2021). Ultimately, effective vocational training programs are crucial for empowering individuals with intellectual disabilities to reach their full potential and lead fulfilling lives.

Despite the benefits of vocational training, individuals with intellectual disabilities often face significant barriers to employment. Unemployment rates for this group remain alarmingly high,

highlighting a pressing issue in workforce integration (Wehman et al., 2014). For instance, in the United States, the unemployment rate for individuals with disabilities is approximately 7.2%, significantly higher than the 3.5% rate for individuals without disabilities (U.S. Bureau of Labor Statistics, 2023). In the United Kingdom, this disparity is similarly pronounced, with 7.1% of individuals with disabilities being unemployed compared to only 3.5% of those without disabilities (Department for Work and Pensions, 2023). In Saudi Arabia, where the current study is conducted, only 41.6% of individuals with disabilities are employed, indicating that nearly 60% remain out of the workforce (General Authority for Statistics, 2020). Furthermore, a global perspective reveals that, despite various vocational training initiatives, individuals with intellectual disabilities still face systemic barriers, leading to unacceptably high rates of unemployment and underemployment.

The previous statistics reveal not only a disparity in employment opportunities but also the need for targeted interventions that address the unique challenges faced by this population. Factors contributing to this gap include limited access to tailored vocational training programs, social stigma, and misconceptions about the capabilities of individuals with intellectual disabilities (Alnahdi, 2014; Almalki, 2022). Additionally, a lack of employer awareness and inclusive hiring practices further exacerbates the problem (Almalki et al., 2021). Addressing these barriers is crucial to creating effective training methods and supportive employment environments that can facilitate skill acquisition and enhance job readiness. Such efforts are essential for empowering individuals with intellectual disabilities, enabling them to achieve greater independence and contribute meaningfully to society (Flynn, 2020).

Various teaching methods have been utilized to enhance vocational skills among individuals with intellectual disabilities. Among these, video modeling (VM) has gained recognition as a highly effective teaching strategy for individuals with intellectual disabilities, particularly in vocational training contexts. This method utilizes video recordings to demonstrate specific tasks, allowing learners to observe and replicate the actions of a model. By capitalizing on visual learning, VM offers an engaging alternative for individuals who may struggle with traditional instructional methods (MacDonald et al., 2005). The clear visual representation of tasks helps bridge the gap between theoretical knowledge and practical application, making it easier for learners to grasp complex concepts.

Lee (2015) pointed out that VM includes several effective types tailored to various learning needs. Basic video modeling presents a straightforward demonstration of a task, allowing learners to observe step-by-step. Video self-modeling enhances motivation by featuring the learner successfully completing the task, while peer-mediated VM uses a peer as the model, promoting relatable learning through social interaction. Lastly, point-of-view VM offers a first-person perspective, immersing learners in the task and providing crucial context. Each type of VM serves to maximize engagement and effectiveness in skill acquisition.

Numerous studies emphasize the effectiveness of VM across various skill domains. A comprehensive meta-analysis by Bellini and Akullian (2007) highlighted that VM significantly enhances social skill acquisition, leading to improved peer interactions and communication among individuals with intellectual disabilities. Additionally, VM has proven effective in teaching daily living skills. For example, Al-Salahat (2016) demonstrated how VM was utilized to teach individuals with Down syndrome to prepare a cream cheese sandwich, resulting in participants

achieving proficiency in just a few sessions. They demonstrated that they continued to use it even 14 days after mastering it. In the realm of vocational skills, Jeong (2023) applied VM in a café setting, revealing marked improvements in independent performance, particularly in cooking tasks, thus reinforcing VM's applicability in real-world vocational scenarios. Moreover, research has shown that skills acquired through VM can be retained over time. For instance, Kanfush and Jaffe (2019) found that participants maintained high proficiency levels in cooking tasks even weeks after the intervention, demonstrating the lasting impact of VM training. This ability to retain skills is crucial for individuals with intellectual disabilities, as it promotes independence and enhances their quality of life.

Despite the promising findings surrounding VM as an instructional strategy, there remains a significant gap in the literature specifically addressing its application within fast-food restaurant settings for individuals with intellectual disabilities. While previous studies have demonstrated the benefits of VM in various educational and therapeutic contexts, such as improving social skills and job-related tasks, there is a lack of focused research on its effectiveness in vocational training programs tailored to prepare individuals for employment in fast-food environments. Exploring this gap is crucial, as the fast-food industry often presents unique challenges and opportunities for individuals with intellectual disabilities. Effective implementation of VM could not only enhance their job readiness but also promote greater inclusion and independence within the workforce. As noted by Jeong (2023), further investigation into this area could lead to more targeted interventions that optimize employment outcomes and support for these individuals.

Purpose and research questions

The primary aim of the current study is to assess the effectiveness of VM as an intervention strategy to enhance the meal preparation proficiency of individuals with intellectual disabilities in fast-food restaurant settings. This investigation seeks to address two key questions: 1) is there a functional relation between VM as a training method for individuals with intellectual disabilities and acquiring proficiency in meal preparation within a fast-food restaurant setting? and 2) how well do individuals with intellectual disabilities remember meal preparation skills they learned through VM after the intervention ends?

Methods

Design

The study used a multiple probe design across subjects. This experimental method helps clarify the relationship between the independent and dependent variables. In this design, data is collected at different times during the baseline phase. The intervention phase begins once the baseline data stabilizes (O'Neill et al., 2011). This design was chosen because the dependent variable shows lasting behavior changes, even when the independent variable is not present. Additionally, this approach is suitable for studying sequential behaviors, where mastering each step depends on the previous one. It is also effective for skill acquisition studies, which requires measurements taken at irregular intervals instead of continuous monitoring, making it easier for researchers (Ledford & Gast, 2018). Moreover, the design's ability to accommodate occasional measurements aligns well with the researchers' needs and the training framework of the institution.

Participants

The study group consisted of four individuals with intellectual disabilities, as detailed in Table 1. Participants were selected based on specific criteria: they had to be newly registered at the training institution and should not have received any prior training in meal preparation to ensure that skill acquisition was solely related to the VM intervention. Individuals needed to have mild to moderate intellectual disabilities, with Intelligence Quotient (IQ) scores ranging from 40 to 70, as per institutional records, while cases of severe disabilities were excluded. Additionally, participants were restricted to ages 18 to 30 years and were required to have normal hearing and vision, as well as the ability to move independently. They also needed to maintain attention for 3 to 5 minutes and demonstrate consistent attendance and good behavior, such as staying seated, following instructions, and avoiding distractions, without the use of medication for behavioral control. This selection process ensured a well-defined study group, allowing for a focused examination of the VM intervention's effectiveness.

[Table 1 about here]

Setting

During all phases of the study, sessions were held in an environment designed to closely resemble real-world conditions. The training facility included a simulated fast-food restaurant associated with a well-known Saudi food corporation. In this setting, the cashier and cooking stations were carefully constructed, along with the order preparation area, which featured necessary items like beverage dispensers, paper bags, and condiments such as ketchup and mayonnaise. Additionally, there was a meal preparation area equipped with essential equipment, including barbecue grills, frying machines, sandwich assembly tables, and containers for sandwich ingredients like vegetables, cheese, and spices. To maintain the integrity of the study, each participant received individual training sessions, which helped prevent any potential contamination of treatment effects due to observational learning or influence from previous participants, thereby preserving internal validity. Moreover, steps were taken to minimize external disturbances in the study environment, ensuring low noise levels and limited interference from staff within the institution.

Materials

In this study, a tablet device was used to present a video demonstrating the steps involved in meal preparation. The video featured an external trained instructor performing the task, captured from multiple angles to provide a clear and comprehensive view for students to emulate. This method is considered to be a basic form of VM. To measure participants' skills, we defined "independent performance" as the ability to complete each task step without prompts or assistance (Kim, 2018). Additionally, we developed several forms for the research: 1) a participant selection form outlining the criteria for inclusion, 2) a data collection form detailing both the independent and dependent variables along with a breakdown of the task steps, 3) the tablet device for video playback, 4) Bluetooth headphones for audio-visual engagement, and 5) all necessary materials for meal preparation, including sandwich ingredients, condiments (like ketchup and mayonnaise), napkins, beverages, fries, and a carry bag for transporting the meal.

Procedure

Baseline

The baseline phase involved collecting data from four participants over at least three sessions each. We chose to limit the number of sessions to three to avoid overwhelming the participants while still capturing stable data patterns (Nam et. al., 2014). During these sessions, participants were instructed to prepare a complete burger meal, similar to what one would typically receive at a restaurant. The researchers recorded detailed observations on standardized forms, counting how many steps each participant completed correctly. This method allowed us to track which steps the participants had mastered. Importantly, during the baseline phase, no instructions or feedback were provided by the specialist, ensuring that the observed performances were unaffected by external cues.

Intervention

After all participants completed their baseline measurements and demonstrated stable data, we began the intervention with the first registered participant. We continued this process sequentially until each participant met the predefined proficiency criteria. During the intervention sessions, participants watched an instructional video only once before each session. This video demonstrated the skill steps on a tablet while they wore headphones to minimize distractions, and they were seated at a designated side table.

The specialist provided clear instructions, encouraging participants to focus on the video and replicate the demonstrated skills. Participants were invited to ask for help if they had difficulty executing any skill. The specialist used a structured approach for error correction, starting with subtle prompts and advancing to direct instruction as necessary. For instance, participants might be asked to recall the next step or given choices to aid their self-correction. If they continued to struggle, the specialist provided verbal guidance while participants performed the steps alongside the specialist. If a participant was unable to execute the step independently, their response was considered incorrect. Notably, the level of assistance was gradually reduced across the intervention sessions. Observers recorded participant responses on standardized forms, noting instances of correct skill application or self-correction after receiving verbal assistance. Additionally, the specialist offered verbal reinforcement after each accurate response, providing praise such as "well done" or "excellent job."

Maintenance

In order to ascertain the participants' retention of the newly acquired skill, assessments were administered at the conclusion of the intervention phase and again one to two weeks thereafter. Retention evaluations mirrored the procedures employed during baseline measurements, notably excluding the utilization of VM interventions.

Dependent variables

The main variable being studied is proficiency in meal preparation tasks within a fast-food restaurant. This skill was evaluated through a systematic analysis of the sequential tasks involved in meal preparation, a method commonly used in research that employs VM strategies (Ashram, 2021; Kanfush & Jaffe, 2019; Shepley et al., 2017). The evaluation followed a defined ten-step sequence (Table 2). Two external observers identified and recorded the steps that were executed correctly. Mastery was defined as achieving 100% accuracy across three consecutive sessions, in line with previous research that defines professional competence as a proficiency level of 90-100%

(Kanfush & Jaffe, 2019; Shepley et al., 2017). This structured approach ensures a thorough assessment and establishes a clear standard for proficiency in fast-food meal preparation.

[Table 2 about here]

Independent variables

The VM process began with the careful creation of a detailed representation of the skills needed for meal preparation in a fast-food restaurant. Researchers first visited the establishment to observe former trainees performing the tasks, which helped identify and outline the sequential steps involved. Next, a video was recorded featuring a model (an employee from the Training and Rehabilitation Institution) demonstrating the meal preparation skills in the actual setting. Great care was taken to ensure the video was clear and accurate, making adjustments based on feedback from a trial with a novice trainee not part of the study. Insights from specialists and researchers guided these modifications, along with consultations with two faculty members who specialize in special education for intellectual disabilities and an inclusive education teacher.

The video lasted 2.25 minutes and included audio annotations, which were designed according to standards set by similar studies (Kanfush & Jaffe, 2019; Shepley et al., 2017). The intervention involved participants engaging with the VM process, facilitated by the specialist who presented the video while the participant wore headphones to reduce distractions. After the video ended, participants began implementing the skills, and their responses were recorded by observers.

Observer agreement

Data collection was carried out by trained observers using a standardized data collection form, following detailed instructions from the researchers. This training included a thorough explanation of the dependent variable, along with practical simulations of observations using the forms employed in the study. To ensure reliability among observers, the percentage of agreement was calculated by dividing the number of agreements by the total number of agreements and disagreements, then multiplying by 100 for each stage. It was required that the percentage of agreement not fall below 80%, and ideally exceed 90%, across 33% of the total sessions, in accordance with established methods (Ledford & Gast, 2018). In this study, observer agreement across 33% of the sessions reached 91.7%, which met the criteria for acceptable consistency as per established standards.

Social validity

At the end of the study, the researchers assessed social validity through a survey designed for this purpose. This survey gathered feedback from both participants and specialists about the effectiveness of the intervention and its impact on skill development, as outlined by Horner et al. (2005). Participants responded to five statements that included visual representations of a smiling and a sad face (Table 3). Specialists answered a questionnaire with six statements and three response options (Table 4).

[Table 3 about here]

[Table 4 about here]

Data analysis

After the intervention provider completed the questionnaires, the researchers transcribed the data into Excel spreadsheets for thorough processing and analysis. Graphs were visually inspected to illustrate the effectiveness of the intervention in skill acquisition, with percentages and frequencies calculated for each stage of the experimental design. Proficiency levels were assessed by calculating averages and ranges, while trends in the data were analyzed to evaluate the effectiveness of the VM intervention. A noticeable upward trend would indicate the intervention's effectiveness. Data stability was also evaluated, with a threshold set at no less than 80%, and changes between stages were calculated to show the percentage difference between the final data point in the baseline phase and the initial data point in the intervention phase.

Relative changes were determined by calculating the difference between the medians of the final baseline sessions and the initial intervention sessions to ensure distinctiveness in the data. Additionally, the absence of overlapping data points between phases was confirmed by calculating the percentage of data points in the intervention phase that exceeded the highest data point in the baseline phase, following the Percentage of Non-overlapping Data (PND) metric (Ledford & Gast, 2018; O'Neill et al., 2011).

Results

This section presents the outcomes of using VM as an intervention tool for teaching fast-food meal preparation skills to individuals with intellectual disabilities. Results will be described individually for each participant involved in the study. Additionally, Table 5 shows the percentage accuracy of the targeted skill for each participant and phase, while Table 6 displays the mean accuracy in each phase until mastery.

[Table 5 about here]

[Table 6 about here]

Adam

During the baseline phase, Adam performed the task with 40% accuracy, indicating a low and stable trend. After introducing the intervention, Adam showed immediate improvement, reaching 60% accuracy, followed by significant and consistent enhancement in his meal preparation skills, ultimately achieving 100% accuracy in the last three sessions of the intervention phase. Notably, no verbal assistance was provided to Adam. To assess his retention of meal preparation skills, he maintained 100% accuracy in all maintenance sessions without receiving any verbal support.

John

During the baseline phase, John was able to perform the fast-food meal preparation skills with 20% accuracy, completing two out of the ten steps correctly. However, during the first session of the intervention, he showed immediate improvement, increasing his accuracy to 40%. Unfortunately, a decline in performance to 20% was noted in the second intervention session, which may have been attributed to the participant's health deterioration, specifically an increase in fatigue and discomfort. In the following sessions, John's performance gradually improved, achieving 50% and then 70% accuracy. However, John received verbal assistance only in four middle sessions. He then stabilized at 90% over the next four sessions, although this stability was impacted by an arm injury that caused him to miss three sessions and required more intensive verbal assistance. Ultimately, John reached and maintained a 100% mastery level independently.

in the last three sessions of the intervention. In the maintenance phase, John was able to sustain a 100% performance rate without any verbal assistance.

David

During the baseline phase, David showed a notably low proficiency, scoring only 20%. This result highlights his difficulties in correctly and sequentially completing the task, indicating the need for external intervention to support skill acquisition. With the introduction of the intervention, David's performance improved to a 50% completion rate. However, performance stabilization was observed in a few sessions, along with his absence from one session, which temporarily affected his progress. As a result, the specialist provided extensive verbal assistance during five sessions. After this support, David's proficiency continued to increase, ultimately reaching 100% accuracy in the last three sessions of the intervention without any verbal help. In the maintenance phase, David achieved a score of 90% with some verbal assistance.

Noah

An evaluation of Noah was conducted during the baseline phase to measure his abilities in preparing a fast-food meal. He scored 40% out of 100% in this phase. After the introduction of VM, significant improvement was observed from the start of the intervention. Noah achieved an 80% success rate in executing the required steps during the first session. This positive trend continued, ultimately reaching a mastery level of 100% across three consecutive sessions, all accomplished independently without any verbal guidance. Noah also maintained a score of 100% in the maintenance phase, again without verbal assistance.

Discussion

The study aimed to train participants on a professional skill involving preparing a meal in a fast-food restaurant using VM, in addition to verifying their ability to retain the skill. To achieve the study's objectives, the researchers implemented the training program on four students with mild to moderate intellectual disabilities enrolled in one of the vocational training and rehabilitation institutions for individuals with disabilities in the Riyadh region. The study was conducted using one of the single-subject designs, specifically multiple probe design; this was chosen to suit the study's procedures; with the aim of verifying the functional relationship between the study variables, through the application of study tools, data collection, and then analyzing it for the purpose of deriving and interpreting the results.

The study's findings indicated that during the baseline phase, before any interventions, the four participants did not demonstrate the skill of preparing a meal in a fast-food context. Their correct responses ranged from 20% to 40%, showing a low level of proficiency in executing the necessary steps, with none exceeding a 60% success rate. This performance level remained consistent over three consecutive sessions, underscoring the need for targeted skill training interventions. After implementing virtual modeling (VM) as an intervention, a significant immediate improvement in performance was observed, with increases of up to 40% compared to the baseline phase, ultimately reaching 100% by the end of the intervention sessions. This suggests that VM was highly effective for training two of the four participants in preparing a fast-food meal. The other two participants also benefited from VM, but required additional verbal assistance. In the maintenance phase, three participants were able to sustain their meal preparation skills, achieving a 100% success rate, while one participant achieved 90%.

Overall, the main finding of the present study is that VM is a significant tool to be used with individuals with intellectual disabilities for teaching them employment skills. This finding is consistent with many other studies (such as Al-Ashram, 2021; Kanfush & Jaffe, 2019; Taber-Doughty, 2011) where all of them demonstrated that VM was able to improve the performance of skills such as, coffee preparation, sandwich making, cooking, and meal preparation, high hygiene and wearing clothes.

The findings of this study highlight several important points. First, the researchers observed that Adam was the most advanced participant, showing strong proficiency in the targeted skill. He demonstrated excellent retention of the procedural steps and executed them with exceptional speed, mastering the skill within five sessions. This aptitude may be related to his mild intellectual disability. In contrast, David faced significant challenges. He struggled to recall the procedural sequence needed for skill execution, showed difficulties in implementing the skill, and worked at a slower pace, which was further affected by anxiety. Additionally, he relied heavily on verbal guidance. The researchers believe that David's lower performance may be attributed to his lower cognitive abilities.

For the participant John, despite having mild intellectual disability, he required the most sessions in the intervention phase to achieve mastery, eleven sessions. This was due to physical challenges, specifically a slight hand tremor that reduced speed and precision, compounded by a hand injury in the middle of sessions (17-20), causing him to miss three sessions and affecting his overall performance, which stabilized at a 90% correct response rate after his return. The researchers believe that this stabilization in performance was influenced by the temporary discontinuation of the intervention for three days, which was overcome when the intervention resumed. Surprisingly, Noah who has moderate intellectual disability did an excellent performance better than John (mild intellectual disability), and close to Adam's performance. We believe this is because cooking is one of Noah's habits as he mentioned, and he is planning to have his own food truck in future.

Regarding skill retention, evaluation sessions were conducted two weeks after the intervention for participants Adam and John, both of whom achieved a perfect performance rate of 100%. Additionally, a single session was held for participants David and Noah one week after the intervention ended, due to the conclusion of the training program. Noah demonstrated his ability by independently achieving a 100% performance score without needing verbal assistance, highlighting the intervention's effectiveness in promoting skill retention. These results align with findings from previous research. For example, Al-Buqami et al. (2022) reported that individuals with autism spectrum disorders were able to maintain skills learned through VM and pictorial aids. Similarly, Kanfush and Jaffe (2019) found that participants retained cooking skills for six weeks, while Scott et al. (2013) discovered that participants could retain skills for using ATMs with the help of VM on iPod devices with auditory guidance.

Conversely, David secured a performance score of 90% and required slight verbal assistance during the maintenance phase. It is posited by the researchers that sustained maintenance sessions might enable independent performance. According to Ledford and Gast (2018), however, rates of 90% or higher are indicative of a highly effective intervention. These findings reinforce the success of the VM approach employed in the present study.

An important factor that improved performance among some participants was the use of VM combined with verbal guidance. For example, John and David experienced difficulties remembering certain steps in preparing fast-food meals. As a result, specialists provided verbal

assistance to help strengthen their procedural memory, particularly for David. The use of verbal prompts enhanced the performance of both individuals. Research by McDuff et al. (2020), Park et al. (2019), Radley et al. (2021), Shepley et al. (2017), Scott et al. (2013), and Taber-Doughty et al. (2011) supports the effectiveness of combining verbal cues with VM to address cognitive challenges associated with intellectual disabilities, such as memory retention and attention focus. Additionally, these studies show that it is possible to gradually reduce the need for external prompts or support. This aligns with the findings of the present study, where participants demonstrated the ability to perform tasks independently after two to four sessions, highlighting the potential for gradually reducing support while allowing them to execute skills using only VM guidance.

The results regarding social validity indicate that the proposed intervention was well received. The researchers developed an illustrated questionnaire for participants, consisting of five statements, along with a short questionnaire for specialists that included six statements. Participants reported positively on the clarity and usability of the video strategy, with statements such as, "I find the video strategy clear and easy to use." They also recognized the strategy's effectiveness in training for the targeted skill, stating, "The video strategy helped me easily prepare the meal." These findings align with previous studies by Kanfush & Jaffe (2019), Taber-Doughty et al. (2011), and Yakubova et al. (2015), all of which support the effectiveness and ease of implementing virtual modeling (VM). Participants also agreed that the strategy enhanced their independence, expressing sentiments like, "I feel that the video has increased my ability to perform the skill on my own." This aligns with research by Al-Ashram (2021) and Taber-Doughty et al. (2011). Additionally, respondents indicated a strong likelihood of using the strategy in the future.

Moreover, participants expressed enjoyment and increased motivation while learning with VM, noting, "I feel enjoyment and enthusiasm using the video strategy in learning." This is consistent with findings from Mechling et al. (2014) and Spivey & Mechling (2016), which demonstrated that VM enhances learner engagement and motivation during interventions. Participants also expressed a desire to use VM for learning other skills in the future, stating, "I want to use video modeling to learn other skills."

On the other hand, the two supervisors at the institution expressed their support for the strategy's role in fostering learning independence and assisting in training professional skills. They responded positively to statements like, "Video modeling contributes to increased independence in training" and "Video modeling helped in training on the professional skill." However, they were less supportive regarding the idea that the strategy reduces training duration. For the statement, "Watching the video contributes to reducing the training duration for trainees," one specialist agreed while the other did not. Both specialists acknowledged the enjoyment of learning with VM, responding affirmatively to, "Video modeling is enjoyable in student training," and expressed interest in using the strategy in the future, agreeing with the statement, "It is possible that I will use the VM strategy to train students in the future."

Limitations

The present study faces several limitations that future researchers should consider addressing. Primarily, the small sample size limits the generalizability of the findings. Furthermore, extending the applicability of the trained skills to actual restaurant environments presents challenges due to logistical constraints. These constraints include the necessity for medical examinations of participants and specific authorizations from the Ministry of Municipal Affairs in Riyadh, which

the limited duration of the training does not support. Additionally, the requirement for medical testing might face objections from the participants' parents. Moreover, the study sample included only male participants; female participants should also have been included. Lastly, the maintenance phase for the last two participants (David and Noah) was confined to a single session because their training period had concluded. To enhance the robustness of future findings, it would be beneficial to schedule more extensive maintenance sessions and allow for a longer hiatus post-training.

Future research

Following the completion of this study, the researchers advise scholars in the field to pursue research on the application of VM strategies in imparting a range of vocational skills. Furthermore, it is suggested that additional investigations assess the efficacy of VM when paired with verbal assistance, as evidenced by the current study's findings that some participants benefited from verbal support during the intervention. There is also a need for studies to evaluate the capacity of VM to generalize vocational skills in populations with intellectual disabilities. Comprehensive research should be conducted into the application of VM for in-service training aimed at improving and developing the professional skills of employed individuals with disabilities.

Disclosure Statement

No potential conflict of interest was reported by the authors.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Graduate Students' Experiences in Special Education: Structural and Relational Barriers in a Middle Eastern Context

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Abstract

This qualitative study explores the lived experiences of graduate students enrolled in a special education program at a Middle Eastern university. Using a phenomenological design, the study investigates institutional, academic, and relational challenges that students encounter throughout their academic journey. Drawing on interviews with sixteen master's and doctoral students, thematic analysis revealed four key areas of concern: 1) curriculum intensity and misalignment, 2) ambiguity and stress in supervision and comprehensive exams, 3) relational disconnect in faculty engagement, and 4) systemic inefficiencies in administrative processes. The findings highlight the misalignment between student needs and institutional structures in non-Western higher education systems. The study offers evidence-based recommendations for curriculum reform, supervisory transparency, faculty development, and administrative streamlining. It also contributes to global higher education scholarship by amplifying underrepresented voices from the Arab region and calling for more inclusive, student-centered approaches to graduate education.

Keywords: Graduate education; student experience; special education programs; higher education reform; Middle East; qualitative research.

Introduction

Graduate education plays a pivotal role in national development and knowledge economies. It cultivates research capabilities, critical inquiry, and domain-specific expertise, preparing graduates to contribute to academic scholarship, industry innovation, and public policy (Boud & Lee, 2005; Sverdlik et al., 2018). As institutions expand postgraduate offerings globally, attention has shifted toward not only increasing access but also improving the quality and sustainability of the graduate student experience (Gardner, 2009; Jairam & Kahl, 2012).

Postgraduate study is inherently demanding, often requiring students to navigate intensive coursework, develop original research, and manage evolving academic identities. These tasks are further complicated by interpersonal dynamics (especially in supervisory relationships) and by the institutional structures within which students must operate (Lee, 2008; Lovitts, 2001). Scholars have consistently pointed to recurring themes: lack of clarity in program expectations, insufficient academic support, administrative inefficiencies, and emotional exhaustion (McAlpine & Amundsen, 2012; Stubb et al., 2011). Although frequently portrayed as individual stressors, these

experiences often reflect deeper systemic and structural issues embedded in graduate education models.

Yet, much of the empirical literature on graduate student experiences has been generated in Western, resource-rich academic systems, contexts in which individual agency, horizontal communication, and liberal academic traditions are more established (Sverdlik et al., 2018). In contrast, studies from non-Western settings, where hierarchical governance, centralized authority, and sociocultural constraints shape institutional life, remain limited. This imbalance in the research landscape not only creates blind spots in global higher education scholarship but also restricts the development of inclusive theories of postgraduate learning and institutional engagement (Al-Farsi, 2018; Badran et al., 2019).

The Arab region presents a compelling case in this regard. Although graduate education has grown significantly over the past two decades, many programs continue to operate within rigid bureaucratic frameworks, with limited student input in academic decision-making and variable access to research support (Maziad et al., 2020). These institutional features are often intensified in specialized fields such as special education, where students are expected to develop interdisciplinary expertise, apply theory in complex field settings, and address the emotional dimensions of working with vulnerable populations (Gu et al., 2020; Mazzotti et al., 2021). However, few studies have explored how these demands are perceived and navigated by graduate students within the region.

Addressing this gap, the present study investigates the lived experiences of graduate students enrolled in a special education program at a leading public university in the Middle East. The study is framed through two theoretical lenses. First, Knowles' (1980) theory of adult learning emphasizes the role of self-directed inquiry, learner autonomy, and experiential relevance, dimensions often overlooked in traditional, lecture-driven graduate programs. Second, Tinto's (2017) model of student persistence highlights how academic integration, institutional support, and a sense of belonging critically shape student retention and success. Together, these frameworks offer a multidimensional perspective on how students interpret and respond to the structures, expectations, and relationships that define graduate study.

By foregrounding the voices of students and unpacking their encounters with academic, relational, and procedural challenges, this research contributes to a more nuanced understanding of postgraduate education in underrepresented contexts. It seeks to answer the following guiding question: What are the primary institutional, academic, and interpersonal challenges experienced by graduate students enrolled in a special education program within a Middle Eastern higher education context? This qualitative inquiry not only fills a regional research gap but also extends global conversations on the future of graduate education, particularly in relation to inclusion, equity, and responsiveness in institutional systems.

Methodology

Study design

In order to investigate the lived experiences of graduate students enrolled in a special education program at a Middle Eastern university, [anonymous university], this study used a qualitative, phenomenological research design. The selection of phenomenology was based on its ability to provide light on how people understand and interpret their academic settings, especially in situations where interpersonal dynamics and institutional processes interact in intricate and frequently under-theorized ways (van Manen, 2016). This method gave students' first-person accounts priority, which made it possible to gain a deep and comprehensive understanding of the difficulties present in graduate school relationships and systems.

Research paradigm and theoretical framing

Based on a constructivist framework, the study recognizes that participant-researcher interaction co-creates knowledge (Lincoln & Guba, 1985). Tinto's (2017) student persistence model and Knowles' (1980) adult learning theory served as the two interconnected theoretical frameworks that drove the investigation. Tinto identifies social and academic integration as essential components of achievement and retention, while Knowles stresses learner autonomy and the necessity of educational relevance. Both the interview design and the analytical emphasis on the relational and structural elements of students' experiences were influenced by these theories.

Participant selection

A purposive sampling technique was used to find participants who could offer meaningful, insightful insights into the problems of postgraduate education. Sixteen graduate students (nine master's and seven doctoral) representing a wide range of academic specializations within the special education program were chosen. All participants were currently enrolled in the program and had completed at least one academic year. The sample includes students at various phases of progress (coursework, comprehensive exams, and thesis development), providing a full picture of the graduate trajectory. To preserve confidentiality, participants were given pseudonyms, and demographic identifiers were kept to a minimum to safeguard anonymity. Table 1 presents an overview of participant characteristics.

[Table 1 is about here]

Data collection procedures

Semi-structured interviews were the primary means of data acquisition. This format struck a compromise between uniformity among participants and the ability to investigate individual experiences in greater depth (Kallio et al., 2016). An interview guide was created using the conceptual frameworks and improved in cooperation with two qualitative research and higher education policy specialists. Questions addressed academic workload, supervision, institutional processes, and emotional well-being, with a focus on how participants made sense of their academic experiences.

To guarantee informed participation, each student was given a written invitation that explained the study's goal, their rights, and the confidentiality safeguards in place. Before each interview, we sought verbal and written consent. Interviews were performed in Arabic and held electronically

using encrypted Zoom video conferencing to account for geographic distance and public health concerns. Each session lasted 45 to 70 minutes and was audio-recorded with consent.

Data management and analysis

All interviews were transcribed verbatim, translated into English as needed, and verified for correctness. Data were analyzed using Braun and Clarke's (2006) six-phase thematic analysis approach, which consists of familiarization, coding, topic development, theme review, definition, and writing. Initial codes were produced inductively and then examined in connection to theoretical frameworks to aid interpretative depth. To improve trustworthiness, several validation procedures were used. First, a group of participants were asked to study preliminary themes and provide feedback on their accuracy and resonance. Second, peer debriefing with two qualitative research colleagues reduced interpretive bias and improved theme building. Third, a reflective research journal was kept throughout the process to help document analytic judgments and increase transparency.

Ethical considerations

The study was authorized by the host university's Institutional Research Ethics Committee. All participants were informed of their right to anonymity, voluntary participation, and the ability to withdraw at any time without consequence. Data was safely saved on password-protected devices and anonymised throughout transcription. In accordance with qualitative research ethics, attention was taken to ensure that participants' voices were conveyed accurately and without distortion (Tracy, 2010).

Findings

The analysis of the interview data indicated a constellation of obstacles that graduate students faced along their academic journey, which were organized into four main themes. These themes represent the structural, relational, and procedural dimensions of their experiences: (1) curriculum intensity and academic misalignment, (2) supervisory uncertainty and emotional burden, (3) relational disconnect in faculty engagement, and (4) institutional fragmentation and administrative barriers. Each theme is supported by illustrated passages and interpreted using adult learning theory and student perseverance models. Table 2 highlights the institutional-level suggestions based on the study of participant experiences in the six primary areas of struggle.

Curriculum intensity and academic misalignment

Across the dataset, participants consistently described their academic workload as excessively demanding and poorly coordinated. Students reported being overwhelmed by concurrent assignments across multiple courses, with limited awareness among faculty of students' total academic load. The perceived absence of curriculum mapping or integrated planning led to overlapping content, duplicated assessments, and diminished intellectual engagement; "each professor gave us four or five assignments without realizing we had other classes. The pressure made it hard to focus, and the quality of our work suffered." (*Participant 6*)

Many students also noted a lack of coherence between coursework and the realities of professional practice. While theoretical instruction was viewed as valuable, the disconnect from applied, field-based learning led to frustration and uncertainty about their readiness for careers outside academia; “we need more practical exposure. The program is heavily theoretical. It doesn't prepare us to deal with students or real-world scenarios.” (*Participant 11*). This theme reflects a misalignment with Knowles’ (1980) adult learning theory, particularly the principles of relevance, problem-centered learning, and experiential application. The curriculum’s rigidity appeared to inhibit self-directed engagement and hindered the development of meaningful academic identity.

Supervisory uncertainty and emotional burden

The second theme centers on the psychological toll of thesis-related processes, including comprehensive exams, supervisor assignment, and research development. Participants characterized the comprehensive exam as a source of profound anxiety, citing ambiguous expectations, absence of preparation resources, and inconsistent communication; “we were told very little about what to expect in the comprehensive exam. There was no structure or guidance, just a vague idea of the topics.” (*Participant 2*).

Supervisor assignment was another area marked by opacity. Students expressed confusion over how supervisors were allocated, with limited opportunities to select mentors based on research alignment or personal compatibility. Several participants shared that supervisors assigned them pre-determined research topics with little regard for their interests. “I had no say in my thesis topic. I wanted to explore inclusive teaching methods, but my supervisor insisted on something else. I didn’t feel any ownership over the work.” (*Participant 4*)

The emotional burden of navigating unclear milestones, lack of agency, and distant supervision amplified stress and contributed to a diminished sense of belonging, contradicting the persistence-supporting conditions outlined by Tinto (2017). Students often internalized these struggles, feeling isolated and unsupported during critical phases of their academic progression.

Relational disconnect in faculty engagement

The third theme reflects students’ perceptions of weak faculty-student relationships, characterized by delayed communication, limited accessibility, and lack of empathetic engagement. Participants described waiting weeks for email responses and often felt uncomfortable following up. There was a notable absence of alternative communication channels or structured check-ins. “When I emailed my professor, I didn’t get a reply until the third reminder. Sometimes I had to speak to them in class just to get noticed.” (*Participant 9*)

Students also recounted experiences of feeling dismissed or misunderstood when navigating personal difficulties. Instances where family, social, or psychological challenges interfered with academic responsibilities were frequently met with indifference or punitive responses from faculty. “I shared that I was dealing with mental health stress, but the professor said, ‘If you can’t handle it, maybe you’re not cut out for this.’ I felt humiliated.” (*Participant 7*)

This theme speaks directly to the emotional dimensions of the graduate experience, highlighting how insufficient relational care and rigid faculty expectations erode students' confidence and academic self-efficacy. The absence of inclusive and emotionally intelligent supervision strategies contradicts both adult learning principles and current best practices in doctoral education (McAlpine & Amundsen, 2012).

Institutional fragmentation and administrative barriers

The final theme captures systemic inefficiencies within the university's administrative infrastructure. Students reported confusion and frustration with bureaucratic processes such as admission procedures, course registration, and research proposal approvals. Delays were common, often resulting from unclear procedures or a lack of coordination across university departments. "It took over a month to get my research plan approved because it had to go through so many layers. No one could even tell me the status." (*Participant 10*)

Digital platforms used for registration and payment were described as outdated and frequently malfunctioning, especially during peak periods. Transfer students highlighted an additional layer of inequity, with several courses from other institutions not recognized for credit, leading to course repetition and prolonged program duration; "they didn't accept my previous coursework even though the content was nearly identical. I had to retake classes I had already passed." (*Participant 13*)

These procedural inefficiencies reflect what Tinto (2017) conceptualized as institutional barriers to integration, suggesting that poorly designed systems may undermine student persistence irrespective of academic capability. The findings underscore the importance of streamlining administrative processes and embedding transparency into academic governance.

[Table 2 is about here]

Discussion

This study explored the lived experiences of graduate students enrolled in a special education program at a [anonymous university], highlighting structural, relational, and procedural challenges that shaped their academic journeys. Through a phenomenological lens, and informed by adult learning theory (Knowles, 1980) and the student persistence model (Tinto, 2017), the findings reveal how institutional systems and faculty practices can either support or erode students' sense of agency, engagement, and progress.

Misalignment between curriculum design and adult learning principles

The theme of curriculum intensity and redundancy illustrates a disjunction between program structure and the learning needs of adult students. Knowles (1980) emphasizes that adult learners thrive in environments where learning is relevant, problem-centered, and practically applicable. Yet, participants described a curriculum that was heavily theoretical, lacked integration across courses, and offered limited opportunities for field-based application. This mirrors concerns raised

in previous research about the failure of graduate programs to connect academic content with professional practice (Gardner, 2009; Mazzotti et al., 2021).

Moreover, the repetition of content across courses and the lack of curricular scaffolding reduced students' motivation and engagement, outcomes that run counter to the andragogical principle of purposeful learning. These issues may be exacerbated in systems where academic planning is decentralized at the instructor level, without broader programmatic coordination (McAlpine & Amundsen, 2012). The findings suggest an urgent need for curriculum audits that prioritize coherence, reduce redundancy, and emphasize experiential learning.

Supervisory structures and the emotional terrain of graduate study

The second theme, centered on supervisory ambiguity and emotional stress, aligns with a substantial body of literature emphasizing the centrality of supervision in graduate student success (Lee, 2008; Ives & Rowley, 2005). Students in this study described not only a lack of clarity in expectations but also limited agency in shaping their research trajectories. The practice of assigning research topics without mutual negotiation undermines students' intellectual ownership and reinforces a hierarchical model of supervision, one that contradicts contemporary views of the supervisor-student relationship as collaborative and developmental (Sverdlik et al., 2018).

Additionally, the emotional toll of vague examination structures and inconsistent guidance is consistent with prior studies documenting how institutional uncertainty can lead to heightened anxiety, academic disaffection, and dropout intentions (Lovitts, 2001; Stubb et al., 2011). Tinto's (2017) model argues that institutional clarity and structured support are foundational to student persistence, conditions that were notably absent in the students' narratives. Institutions must therefore re-examine how supervisory systems are operationalized, ensuring transparency in topic selection, expectations, and evaluation criteria.

The relational dimension of graduate experience

The findings further illuminate a significant relational gap between faculty and students. Delayed responses, rigid communication norms, and perceived lack of empathy signaled to students that they were peripheral to the academic community, an outcome antithetical to Tinto's notion of social integration. Participants' accounts of emotional dismissal during times of personal hardship raise ethical and pedagogical concerns, especially given the recognized link between faculty support and academic resilience (Fumasoli et al., 2014; Gu et al., 2020).

This relational disconnect is particularly problematic in graduate education, where supervision is not just an instructional role but also a form of mentorship. Faculty development initiatives that prioritize emotional intelligence, inclusive advising, and trauma-informed pedagogy could help bridge this gap. In contexts where hierarchical norms constrain open dialogue, structural reforms (such as institutionalizing mentorship check-ins or creating faculty-student liaisons) may serve as relational buffers.

Bureaucratic burden and institutional disintegration

The final theme of administrative inefficiency reflects a broader tension between institutional expansion and administrative capacity. Similar to observations in other regional contexts (Badran et al., 2019), participants described navigating opaque processes, technological malfunctions, and unclear pathways to academic progression. These systemic frictions not only wasted time and energy but also undermined students' confidence in institutional fairness and responsiveness. In Tinto's (2017) terms, these barriers constitute "institutional noise," disruptions that distract students from academic integration and progress. Moreover, the lack of consistency in credit recognition for transfer students raises equity concerns and contradicts international calls for flexible and transparent academic mobility frameworks (Altbach et al., 2010).

To address these issues, institutions must adopt a systems-thinking approach to administrative reform. Digitizing workflows, implementing case management systems, and providing real-time updates on academic procedures are basic but essential steps. Furthermore, embedding student feedback loops into academic governance can ensure that policy development is informed by actual student experience rather than assumed efficiency.

Regional specificities and global implications

Although grounded in a single institutional context, the findings of this study speak to global challenges in graduate education, especially within under-researched, non-Western systems. The structural and relational dilemmas described here reflect broader issues of misalignment between institutional culture and student-centered practice. They also reinforce critiques of graduate education as an emotionally taxing journey, particularly when support systems are fragmented or absent (Jairam & Kahl, 2012; Soria et al., 2020).

Importantly, the study contributes to diversifying the global conversation on graduate education by providing contextually situated evidence from the Arab region. As many journals strive for greater inclusivity in higher education research, amplifying such voices is critical for building responsive and culturally grounded educational models.

Conclusion and implications

The academic and institutional difficulties faced by graduate students enrolling in a special education program at a Middle Eastern university have been examined in this study. The results, which are based on phenomenological research and placed within the frameworks of student persistence models and adult learning theory, show that curricular incoherence, supervisory ambiguity, relational distance, and administrative inefficiencies all influenced graduate school experiences. Even though the issues raised are very specific, they speak to universal worries about the standard, fairness, and mental stability of graduate education.

At the heart of these findings is a misalignment between institutional structures and the developmental needs of adult learners. Students navigated fragmented curricula, limited agency in research engagement, and bureaucratic hurdles that impeded academic integration and personal growth. Despite their aspirations, many described a sense of alienation from both faculty and

institutional processes a sentiment that threatens not only academic performance but also psychological well-being and long-term persistence.

Theoretically, this study contributes to graduate education literature by contextualizing student experiences within a non-Western, hierarchically organized academic setting, and one that is often overlooked in comparative higher education research. It underscores the need to expand dominant models of graduate student development to account for institutional rigidity, sociocultural hierarchies, and the absence of relational care. Practically, the study highlights critical areas where institutional interventions can support student flourishing, particularly in specialized programs that demand interdisciplinary knowledge and emotional resilience.

Policy and practice recommendations

Based on the findings of this study, several recommendations are proposed to enhance institutional policies and academic practices in graduate education. One of the key areas requiring attention is curriculum development. Academic departments should engage in regular reviews to ensure that course content is logically organized, free of unnecessary repetition, and designed to build knowledge progressively. In addition to theoretical learning, programs should incorporate experiential components that help students apply their academic knowledge to real-world professional situations. A well-organized curriculum supports adult learners by emphasizing relevance, practical application, and coherence throughout the learning process.

Another important recommendation concerns the structure and quality of academic supervision. Institutions should adopt transparent processes for assigning supervisors, ensuring that student and faculty research interests are appropriately matched. Furthermore, universities are encouraged to offer targeted training for faculty members to enhance their skills in mentoring, emotional intelligence, and student-centered supervision. Such training equips faculty to support students not only in their research activities but also in navigating the emotional and academic challenges often associated with graduate study.

Improving faculty-student engagement is also critical. Institutions should establish consistent and accessible communication practices that encourage meaningful interaction. This can include regular mentorship sessions, virtual office hours, and departmental advisory initiatives that create space for dialogue. Moreover, communication should not be limited to email; universities should consider using a variety of digital platforms to facilitate more immediate and supportive exchanges. These efforts can significantly reduce student isolation and improve overall engagement.

Administrative systems within universities must also be reformed to better serve graduate students. Centralizing key services (such as course registration, tuition payments, and research approvals) through digital platforms can reduce confusion and administrative delays. Providing students with access to real-time tracking of their administrative progress would also increase transparency and satisfaction. Streamlining these processes is essential to creating an efficient and student-friendly academic environment.

Equally important is the need for clear and consistent policies related to academic mobility and the recognition of prior learning. Institutions should adopt standardized rubrics for evaluating transfer credits to ensure fairness and reduce subjectivity. This is especially crucial for students moving between programs or institutions, as it helps to prevent unnecessary repetition of coursework and supports academic continuity.

Finally, student perspectives should be meaningfully integrated into institutional decision-making processes. This can be achieved through structured feedback mechanisms such as surveys, student panels, and inclusion in academic committees. Listening to students and taking their input seriously is essential for building an inclusive, responsive, and accountable graduate education system that reflects the needs and experiences of its learners.

Directions for future research

While this study gives valuable insights into a single institutional environment, future research should use cross-institutional and cross-cultural designs to assess how diverse governance forms, cultural settings, and academic traditions impact graduate student outcomes. Longitudinal research is also required to determine how institutional modifications affect student persistence, mental health, and career outcomes over time. Finally, including the viewpoints of academics, program directors, and administrative staff may result in a more comprehensive understanding of the relational ecologies of graduate education.

Limitations

Although this study provides insightful information about graduate students' experiences in a special education program in the Middle East, it should be noted that it has a number of drawbacks. First, the study was limited to a specific academic department and institution, which would have limited the findings' applicability to other higher education environments or fields. Secondly, the survey only considered the opinions of students, leaving out the opinions of administrators, instructors, and support personnel, all of whom have a significant influence on the graduate experience. Third, because the data is cross-sectional, it might not accurately reflect how students' perceptions have changed over time. These drawbacks point to the necessity of longer-term, multi-stakeholder studies to confirm and expand on the results reported here.

Conflict of Interest Statement

The author declares no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Categorical and Non-Categorical Approaches to Special Education Teacher Preparation in Saudi Universities

Saeed Almalki

Abstract—Debates on the structure of special education teacher preparation have lasted for decades. Among the central issues is whether teacher training programs ought to be guided by a categorical model, which supports specialization in a specific disability, or a non-categorical model, which prepares teachers more broadly to work with diverse learners. This paper explores both models, synthesizes international perspectives, and considers the modern context in Saudi Arabia. It determines the strengths and limitations of the categorical approach and proposes a semi-categorical model that will balance specialization and flexibility. It argues that the hybrid model will improve program diversity, remove redundancy, and provide a closer alignment between teacher preparation and inclusive education policy. The paper also provides concrete recommendations on how the model can be applied in Saudi universities.

Keywords—Special education, teacher preparation, categorical, non-categorical, inclusive education.

I. INTRODUCTION

THE preparation of special education teachers has been the target of decades-long policy and academic controversy. Arguably the most lasting question has been whether the university should strengthen specialization within particular disabilities or pursue more universal, comprehensive programs. In countries such as the United States, it has shaped teacher certification policy for over 50 years. Early studies questioned the long-term success of categorical certification [1], [2]. Nowadays, the problem remains relevant worldwide as education systems try to maintain specialist depth versus inclusive education demands [3].

Globally, the debate has been underpinned by a shift in conceptualization of disability and inclusion. Whereas categorical models constitute a medical or deficit-conceptualization tradition with an appreciation for specialization, non-categorical models draw on rights-based and social conceptualizations that place emphasis on inclusion as being an integral educational principle [4]. Certain countries, such as Finland and the United Kingdom, have moved away from categorical preparation to support inclusive schooling [5], while others, such as Saudi Arabia, are still closely tied to categorical forms. Recent research highlights that both models are still contested, and there is a growing worldwide interest in hybrid approaches that fuse the advantages of specialization and inclusivity [6].

The purpose of this paper is to compare and contrast categorical and non-categorical approaches to special education teacher preparation and to examine the Saudi situation in particular. The paper provides a global perspective, reviews the theoretical foundation of both models, and surveys the current program design in Saudi universities. On this foundation, it suggests a semi-categorical approach designed to address the aims of specialization and flexibility. This model is geared towards aligning early teacher preparation with the Vision 2030 vision, addressing the demand of the labour market, and increasing the country's ability to provide inclusive education for students with disabilities [7].

II. LITERATURE REVIEW AND GLOBAL PERSPECTIVES

Special education teacher education research has followed two dominant paths: categorical and non-categorical orientations. Both reflect different philosophies about the best method to prepare teachers to address the needs of students with disabilities. The categorical model is specialized within individual disability categories, while the non-categorical model supports broader preparation to address diverse learners in inclusive environments. Worldwide, the two models have influenced policy, practice, and research [3], and many systems continue to grapple with the strengths and limitations of both. Framing these perspectives provides the basis for examining the Saudi context and for developing teacher preparation models that are locally relevant and globally acquired.

A. Categorical Approach

The categorical model trains teachers with high specialization in a single area of disability, i.e., autism spectrum disorder, intellectual disability, or hearing impairment. The approach remains common in Saudi Arabia, Italy, Spain, France, and some U.S. states. Its proponents are convinced that specialization ensures quality services tailored to the characteristic needs of a disability group [4]. Evidence in Europe suggests that categorical preparation has the ability to facilitate high-level instructional practices as well as pedagogical innovation in specific disabilities [5].

Historically, categorical teacher preparation arose from medical and deficit-based models of disability, in which each impairment was treated as an individual category requiring differential interventions. Professional standards were formed

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through this model but also perpetuated segregation in practice. In Saudi Arabia, and throughout the Middle East, categorical model adoption was facilitated through initial American university partnerships throughout the 1980s, thus leading to departmentalization of special education by disability [6]. Current research indicates that specialization remains a factor in teacher identity and continuing professional development, but could also limit adaptability in inclusive environments [7].

B. Non-Categorical Approach

The non-categorical model educates teachers to support all students across disability groups through broad general principles of inclusion and special education. The model is practiced in Finland, the United Kingdom, and Sweden, where it is consistent with inclusive education national policy [8]. Critics of classification argue that it entrenches segregation and restricts inclusion to the classroom [9]. Instead, non-categorical programs attempt to produce responsive teachers who are able to respond to diverse needs, and often look to models such as Universal Design for Learning (UDL) [10].

As an alternative to the categorical model, non-categorical teacher preparation emerged in the context of rights-based and social models of disability. In Finland, for example, inclusive teacher preparation was the central site of reform, preparing teachers to teach in diverse classrooms without labelling children by impairment. Graduates of these programs repeatedly report higher readiness to collaborate, co-teach, and integrate inclusive teaching strategies [11]. Recent comparative analyses highlight that non-categorical frameworks, supported with serious professional development, can build teachers' confidence in addressing variability among students and strengthen inclusive school cultures [12].

III. THEORETICAL CONSIDERATIONS

Inclusive pedagogy makes educators' work to design learning experiences for all learners, rather than those grouped by disability [8]. UDL supports curriculum design based on learner difference through multiple means of engagement, representation, and expression [9]. They challenge absolute categorical distinctions.

At the same time, studies caution that overgeneralized preparation may lead to teachers being inadequately prepared for teaching students with intense or complex disabilities [10]. Special education High-Leverage Practices (HLPs) like explicit instruction, working with families, and monitoring progress indicate the need for both general strategies and disability-specific knowledge in teacher preparation. A blended model, in turn, can be best ideally suited to achieve a balance between inclusivity and depth.

For Saudi Arabia, theoretical thought also entails Vision 2030, which centres on building an educated workforce, broadening access to high-quality education, and making sure to include people with disabilities. Combining teacher preparation with such values requires a framework that embraces categorical depth and inclusive breadth.

IV. THEORETICAL CONSIDERATIONS

Teacher preparation in special education is shaped by broader theoretical debates across inclusion and curriculum planning. Pedagogy of inclusion places the responsibility on teachers to create learning experiences that encompass all children and not merely those who have officially acknowledged disabilities [13]. The approach rethinks diversity as a fundamental feature of classrooms and requires teachers in assuming adaptable, responsive stances that move beyond traditional constructions of differentiation.

Another closely aligned model is UDL, which advocates for the design of curriculum that foresees and adapts to student difference through multiple means of engagement, representation, and expression [14]. New research suggests UDL's use in teacher preparation as growing pre-service teachers' capacity to differentiate instruction, integrate assistive technologies, and remove barriers to participation [15]. If applied in post-secondary education, the principles of UDL can also ensure that teacher preparation programs themselves model the inclusive practices they attempt to impart.

At the same time, researchers caution that a solely non-categorical approach threatens to leave teachers ill-equipped to teach students with high-incidence or severe disabilities. HLPs such as explicit instruction, family engagement, and systematic monitoring of progress require general pedagogical competence but also disability-specific knowledge [16]. Without special preparation, teachers risk falling short on depth of knowledge for students with high-complexity needs. Thus, the hybrid model that blends general inclusive training and selective specialization is more appropriate in preparing teachers for the realities of multiracial classrooms.

For Saudi Arabia as well, theoretical considerations must also be in alignment with national priorities. Vision 2030 emphasizes inclusive education, human capital growth, and labour market readiness. This necessitates that teacher preparation can no longer be maintained as being associated with categorical paths that risk oversupply in some fields while neglecting new demands. Program contents instead should license teachers who are agile, evidence-based, and capable of practicing to meet inclusion. Recent research in the Gulf emphasizes that collaboration between teacher training and international inclusion models, as well as national development plans, is essential for lasting change [17].

V. CURRENT REALITY IN SAUDI ARABIA

Saudi universities currently host approximately 24 special education departments, most following the template set at King Saud University in 1984. Departments take categorical tracks at graduate and undergraduate levels, normally addressing learning disabilities, intellectual disabilities, hearing impairment, and emotional/behavioural disorders [18]. This structure played a key role in setting up the first professional foundation for special education in the Kingdom, supplying an uninterrupted supply of specialists to schools and rehabilitation centres.

Over time, however, this reliance on category models has

revealed a series of challenges. Specializations and curricula remain very similar in various institutions without differentiation or innovation. The country-wide duplication of the same model has led to inefficiencies such as overproduction of graduates in certain areas and excessive staffing requirements [19]. For example, the majority of universities continue to concentrate on intellectual disabilities and learning disabilities in the wake of labour market data showing growing demands for autism experts, applied behaviour analysts, and inclusive classroom facilitators. Recent evaluations of Saudi higher education highlight the need for program retooling to more appropriately reflect workforce demands and inclusive schooling initiatives [20].

Regional disparities compound the complexity. Large urban universities in Riyadh, Jeddah, and Dammam generate large quantities of special education teachers, but rural and peripheral regions tend to suffer from shortages. General education teachers in such areas are normally short in number without the proper training in numerous categories, leading to their dependence on general educators who might receive minimal training in special education [21]. Such imbalance generates service inequalities and sabotages national efforts for inclusive education.

The current system also intensifies the strain on faculty and institutional resources. The maintenance of several categorical tracks requires significant levels of staffing and expertise, which may be difficult to sustain. A few universities have reported difficulties in recruiting faculty in all of the disability categories, resulting in high course loads, resorting to using part-time faculty, or outdated curricula. These factors result in limited innovation and unequal program quality [22].

Finally, the categorical model suggests glimpses of Saudi Arabia's Vision 2030 reforms. National policy emphasizes efficiency, inclusion, and human capital development, but the existing system continues to reproduce specialized pathway tracks with little flexibility. Without reform, graduates will be very well-equipped to perform in specialized institutes but less likely to do well in inclusive schools, which are increasingly dominating national education policy [1]. These facts stress the importance of exploring possibilities such as the semi-categorical model proposed in this paper.

VI. STRENGTHS AND LIMITATIONS OF THE CURRENT MODEL

The Saudi Arabian categorical model of teacher preparation has been key to constructing the special education profession. However, as schooling systems transition toward inclusion, the relevance of this model needs to be weighed against its rising limitations. An honest examination reveals why reform increasingly is necessary.

Conversely, however, the categorical model has certain advantages. It makes it possible for teachers to develop specialist knowledge, ensuring interventions are tailor-made for the specific groups of disabilities. Saudi Arabia has seen generations of special education teachers with specialized expertise in areas such as intellectual disability and hearing impairment, creating possibilities for the development of specialist institutes and resource rooms [2]. Specialization has

also had the impact of professionalizing the profession through the promotion of research and culturally adapted curricula tailored to distinctive disability categories. Recent research outlines how categorical training can be used to build teacher identity and self-confidence, which remain crucial in environments where disability-specific expertise is highly prized [3].

On the other hand, several limitations have arisen. Expert training usually restricts teachers' adaptability in inclusive classrooms, where they must respond to varying learners' needs at the same time [4]. Typical curricula in universities restrict innovation, and categorical frameworks necessitate undue faculty resources compared to global standards [5]. Moreover, recent evidence suggests that producing large quantities of experts in the same fields of disabilities (learning and intellectual disabilities) results in inefficiencies and labour market mismatches [6]. Graduates may be left with great skills in narrow areas but lack the broader skills to collaborate with colleagues, support inclusive pedagogy, or transition with evolving workforce demands [7].

Collectively, these problems suggest that although the categorical model has been fulfilling country requirements for quite some time, it is becoming more incompatible with Saudi Arabia's Vision 2030 program and international movements in inclusive education. The model's strengths ought not to be discarded but its weaknesses highlight the need for exploring more flexible frameworks that balance specialization and inclusive readiness.

VII. PROPOSED SEMI-CATEGORICAL MODEL

Based on global and Saudi experience, this article proposes a semi-categorical model for revamping special education teacher preparation. The model acknowledges the historical importance of categorical preparation in establishing professional standards but introduces greater flexibility to accommodate current education needs. It is designed to balance depth of knowledge with inclusive readiness, enabling Saudi universities to respond to personnel shortages as well as Vision 2030 educational reform targets [8].

A. Research Universities

Research universities such as King Saud University, King Abdulaziz University, Imam Abdulrahman bin Faisal University, King Khalid University, and the University of Hail would take a leading role in implementing this framework. At the graduate level, these universities would offer courses only in non-categorical formats to ensure that students are equipped to serve the needs of diverse learners in inclusive settings. They would also be encouraged to provide new master's programs, such as Applied Behaviour Analysis, inclusive instructional technology, or cross-disciplinary studies in education, psychology, and rehabilitation sciences.

In addition, research universities can establish higher diplomas in specializations such as sign language, visual impairment, and behaviour analysis and therefore keep disability-specific expertise where it is most useful. Establishing research centres specializing in inclusive

education and forging international collaborations would also make such universities drivers of innovation and policy leadership in special education [9].

Example of implementation: King Saud University could establish a Centre for Inclusive Education Research in partnership with Riyadh schools to pilot UDL practices and high-leverage instructional strategies. Graduate students in a newly established master's degree program in inclusive education would conduct school-based research projects, with theory linked to practice. Such a program would enhance the evidence base for inclusive reform and capacity for future teacher leaders.

B. Teaching Universities

Public universities that are regionally or teaching mission-oriented would primarily have undergraduate programs and limited graduate offerings. They would be free to determine whether or not to adopt categorical or non-categorical models depending on regional workforces' needs to meet local requirements.

Teacher education universities could also expand their role by creating diploma programs for paraprofessionals, including transition coordinators, teaching assistants, and behaviour support personnel. These programs would initiate portable training opportunities for an increasingly valuable body of workers within inclusive schools. With modular diplomas and certificates, teacher education universities could respond quickly to shifts in the job market while maintaining pathways to ongoing professional development [10].

Example of implementation: A regional university such as the King Khaled University would embark on categorical preparation in intellectual disability to address near-term local demand, with a diploma program for instruction assistants aimed at inclusive classroom assistance. Over time, this two-pronged format would generate both technical knowledge and adaptable support personnel, addressing workforce gaps in under-served rural areas.

VIII. ANTICIPATED BENEFITS

The proposed semi-categorical model has general benefits that cut across higher education, schools, and the overall labour market. At the system level, it diversifies program structures as it allows universities to create distinctive strengths rather than replicating the same categorical tracks in all universities. Such diversification induces innovation, stimulates healthy competition, and contributes to a more balanced national teacher preparation system [11]. It also maintains program design responsive to labour market needs, preventing oversupply in certain specializations and addressing new emerging shortages, e.g., autism specialists and inclusive education facilitators. Aligning program offerings with workforce demand improves efficiency and the employability of graduates [12].

At the institutional level, the model allows for better faculty allocation and program sustainability. By merging some programs into larger non-categorical models, colleges and universities can ease the staffing difficulties of maintaining

multiple categorical tracks, freeing up resources for areas of great need and research development [13]. At the same time, the introduction of diploma programs for paraprofessionals (teaching assistants, transition coordinators, and behaviour support staff) creates professional career paths and helps schools fill long-standing workforce shortages [14]. These diploma programs provide not only practical answers to school staffing dilemmas but also an upgraded role for paraprofessionals as respected members of inclusive education teams.

At the school and classroom level, the semi-categorical model ensures that graduates are better equipped to support heterogeneous learners. Teachers trained in non-categorical approaches will enter the profession with greater flexibility, while categorical specialists continue to provide targeted expertise for students with complex needs. This dual preparation strategy bridges the divide between general and special education so that inclusive classrooms benefit from both depth and breadth of knowledge [15]. Incorporating evidence-based frameworks like UDL and HLPs into preparation programs also strengthens teachers' abilities to differentiate instruction, collaborate with colleagues, and work with families [16].

Finally, the model facilitates research and international visibility. Graduate research universities that utilize non-categorical graduate programs and inclusive education centres can emerge as hotspots of innovation and international cooperation. These initiatives not only produce new knowledge but also increase Saudi Arabia's voice in international teacher preparation reform discourse [17]. Importantly, this trajectory is concordant with Vision 2030 ambitions, which emphasize knowledge creation, education efficiency, and building a human resource foundation that can respond to future needs [18].

Taken together, these projected advantages illustrate how the semi-categorical approach can shift teacher preparation in Saudi Arabia onto a trajectory of higher efficiency, inclusivity, and global relevance. By compromising between specialization and flexibility, the model offers a viable pathway for reform that is responsive to national needs while making a contribution to international best practices.

IX. IMPLICATIONS FOR POLICY AND PRACTICE

The semi-categorical model has profound policy implications for schools, university leaders, and policymakers. For the Ministry of Education, adopting this framework would require changing accreditation standards to give universities more flexibility in creating programs rather than insisting on uniform categorical tracks. International experience is that flexible accreditation policies can encourage program innovation without abandoning accountability [19]. In the Saudi context, updated national standards could cause institutions to balance categorical mastery and non-categorical readiness, ensuring consistency while leaving room for local adaptation.

For universities, the model requires careful strategic planning about whether to prioritize research-intensive or teaching-

oriented missions. Research universities would need to invest in graduate-level non-categorical programs, advanced diplomas, and foreign affiliations, while teaching-oriented universities would specialize in undergraduate preparation and paraprofessional instruction. Pilot projects can be started in selected universities to try out the feasibility of shifting to non-categorical graduate modes, with evaluations in mind for curriculum design, student competency, and labour market performance [20]. Pilots' results would inform gradual national adoption.

At the school level, the model has the ability to upgrade the teaching profession by ensuring inclusive generalists and categorical specialists. Non-categorical-trained teachers would be better able to meet a range of classroom needs, and categorical specialists would be able to provide specialized assistance for students with complex disabilities. Policymakers also need to establish financing mechanisms and incentive systems that encourage collaboration between schools and universities, allowing for collaborative professional development programs, research in school settings, and practicum placements [21]. This kind of partnership ensures that teacher education is closely linked to classroom realities.

Finally, the model fits like a glove with Saudi Arabia's Vision 2030 reform agenda of efficiency, inclusiveness, and developing human capital. By combining specialization with inclusive preparedness, the semi-categorical model positions Saudi Arabia as a vanguard of Gulf innovative teacher education reform. More generally, the model adds to global debates on balancing inclusion and specialization, providing a context-sensitive approach that could be used to guide policy and practice in other nations experiencing similar issues [22].

X.CONCLUSION

The longstanding debate between categorical and non-categorical models of teacher preparation is echoed in the overall dilemma of balancing depth of knowledge with flexibility in inclusive classrooms. Even though categorical preparation has historically been the foundation for professionalization in Saudi Arabia, its limitations are now glaringly evident in a system shifting towards inclusion. Non-categorical approaches, conversely, promote flexibility and inclusivity but can leave teachers inadequately prepared for students with complex needs.

This paper has argued that a semi-categorical model presents a context-sensitive solution. In distinguishing the missions of research-led and teaching universities, the model upholds the advantages of specialization where needed while opening up more prospects for inclusive readiness. Practically, this approach aligns with Vision 2030 goals by promoting efficiency, maximizing human capital, and enabling the mainstreaming of disabled students into general schools. It also addresses inefficiencies in faculty allocation, workforce mismatches, and the lack of innovation in current programs.

The model has international implications. The semi-categorical model contributes to the international debate on special education teacher preparation by presenting an intermediate stance between excessive specializations and too

generalist approaches. Other hybrid models are also under consideration internationally as education systems seek to pursue equity, inclusion, and efficiency [1]. Pilot trials of the model need to be evaluated in future studies, particularly regarding teacher effectiveness, student outcome, and system sustainability.

In the end, the semi-categorical model provides a viable model for reform that not only enhances special education teacher preparation in Saudi Arabia but also positions the country as a regional model in inclusive education. By embracing an evidence-based practice and inclusive pedagogy, Saudi Arabia can contribute meaningfully to efforts to provide equity and social participation for students with disabilities [2].

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Tax Compliance. Two Institutional Contexts: Flexible or Mandatory

Filadelfo Leon-Cazares

Abstract— The objective of this paper is to describe and explain citizens' tax compliance (TC). Equity theory was used to study the influence of taxpayer perception on a tax system - and its effect on TC. The hypotheses were tested in two contexts. One with tax forgiveness and exemptions and the other with mandatory taxation for all taxpayers. Data provided by 1,191 citizens in 2015 and 867 in 2023 were analyzed with statistical techniques and ordinal logistic regression models. The majority of respondents expressed indifference or agreement with the TC, not knowing the types of taxes at each level of government (local, state and federal) and expressed distrust in government with the use of taxes. Additionally, perceptions of distributive equity were important predictors with the TC. In the flexible context, women were more willing to comply with their tax obligations than their counterparts. In addition, citizens perceived that the government did not repay them with goods and services for the amount of their contributions. However, in the compulsory context, men were more willing to comply with taxes and citizens perceived a fair return for their contributions. In addition, there was better tax collection. In both contexts, education, age and income level were not statistically significant. The importance of this work lies in understanding the complex behavior of citizens with their tax obligations in different contexts.

Keywords— taxes, taxpayers, collection, equity, exemptions.

Long-term Effects of Neonatal Repetitive Pinprick Stimulation on Adult Neuropathic Pain Sensitivity

M. Silva, J. Silva, R. Carolina de Carvalho, A. L. Silva, G. Santos Pereira

Abstract—

Background and aims: Neonatal pain exposure can have lasting impacts on nervous system development, especially in preterm infants who undergo repeated painful procedures. These experiences may predispose them to altered pain processing and chronic pain in adulthood. This study investigates the long-term effects of neonatal repetitive pinprick (PP) stimulation on neuropathic pain sensitivity in adulthood.

Methods: Term and preterm rat pups were assigned to neonatal PP stimulation or control (CC) groups. PP stimulation involved consistent pinprick applications at set intervals. In adulthood, neuropathic pain was induced using a standardized nerve injury model. Mechanical and thermal thresholds were measured with von Frey filaments and a hot plate test, and behavioral pain responses were evaluated. Both male and female rats were included to examine gender differences. Maternal behavior, litter weight, and offspring growth were also monitored for potential developmental impacts.

Results: PP stimulation did not affect baseline nociceptive thresholds in adulthood. However, after neuropathic pain induction, rats subjected to neonatal PP stimulation showed increased mechanical hypersensitivity compared to the CC group, particularly in preterm rats, indicating higher vulnerability due to early exposure. Females exhibited greater hypersensitivity than males, suggesting sex-specific effects. No differences in maternal behavior, litter weight, or offspring growth were observed between groups, indicating no developmental disturbances from the neonatal stimulation.

Conclusions: Neonatal PP stimulation resulted in increased neuropathic pain hypersensitivity in adulthood, with more pronounced effects in preterm rats and females. These findings underscore how early pain experiences can shape long-term sensory processing, emphasizing the potential long-term consequences of neonatal pain, especially in preterm infants.

Keywords— pain, neuropathic pain, preterm rats, neurobiology.

Clinical Impact of Silica and Vanadium-enriched Water in the Management of Oral Mucositis in Palliative Cancer Patients: A Pilot Observational Study

Adriana Mendes

Abstract— Oral mucositis is one of the most frequent and debilitating side effects in cancer patients undergoing chemotherapy or radiotherapy, particularly in palliative care contexts. It causes intense pain, impairs nutrition and oral hygiene, and severely affects the patient's quality of life. This study proposes a low-cost, non-invasive, and integrative approach using water enriched with silica and vanadium to mitigate oral mucositis symptoms in palliative oncology patients. This is a prospective, observational, and exploratory pilot study to be conducted in a Brazilian philanthropic institution specialized in palliative cancer care. A structured hydration protocol will be applied over a period of four weeks, during which patients will consume an average of 1.5 liters per day of silica and vanadium-enriched water, exclusively. Participants will be selected according to clinical criteria: confirmed oncological diagnosis, indication of palliative care, presence of mild to moderate oral mucositis, and cognitive ability to consent and self-report. Clinical evaluation will be conducted weekly by healthcare professionals using adapted oral mucositis scales, and patients will maintain a daily self-report diary including pain scores, hydration, oral comfort, fatigue, nausea, and general well-being. Qualitative data on patient experience will also be collected through semi-structured interviews. Expected outcomes include reduction in mucositis severity, improved oral function, and enhanced subjective well-being during the study period. Secondary observations will include effects on nausea, sleep quality, fatigue, and intestinal function. The intervention's adherence and safety will be monitored continuously. The significance of this research lies in its applicability and simplicity. The use of therapeutic water in this context has not yet been systematically explored and may represent an accessible and humanized form of care, particularly relevant in palliative settings. Furthermore, the study aims to contribute to the growing field of integrative oncology and stimulate further research in the interface between oral health, cancer care, and hydration therapy. This study will be submitted for approval by the Brazilian Research Ethics Committee (CEP) and, once authorized, data collection will begin. The research is entirely self-funded and independent, driven by clinical observation, spiritual responsibility, and the urgent need for solutions that ease suffering at the end of life.

Keywords— oral mucositis, palliative care, therapeutic water, integrative dentistry, oncology.

Royal College of Emergency Medicine Care of Older People Quality Improvement Project Done in University Hospital of North Durham

Ivy Lai

Abstract—

Background: Older adults represent a significant proportion of emergency department (ED) attendances and subsequent hospital admissions. Among this population, delirium and falls are among the most common reasons for presentation. As part of the national Quality Improvement Project (QIP) led by the Royal College of Emergency Medicine (RCEM), a local project was undertaken to evaluate and improve the care provided to patients aged 75 and over presenting to the ED.

Aims: The aims of this project were threefold: first, to improve the screening processes for delirium, frailty, and falls risk; second, to ensure that appropriate actions are taken based on the results of these screenings; and third, to address and meet the basic care needs of older patients during their time in the ED.

Methods: Prospective data were collected from February to November 2024, involving 158 patients aged 75 or older with a NEWS2 score of less than 4. Data were gathered using national RCEM QIP criteria and uploaded to the RCEM QIP platform. Local results were benchmarked against national data comprising 1,997 patients.

Results: Delirium screening using the 4AT tool was performed in only 4% of local cases, compared to 15% nationally. Falls risk assessments were completed in 55.7% of local cases versus 43.8% nationally. Frailty screening using the Rockwood Clinical Frailty Scale was completed in 60% locally, compared to 53% nationally. Delirium management plans were initiated in 33% of relevant local cases, compared to 28.8% nationally. Falls mitigation strategies were implemented in 91.9% of at-risk patients locally, significantly exceeding the national figure of 32.6%. However, Comprehensive Geriatric Assessment (CGA) was initiated in only 6.5% of local cases, compared to 35.5% nationally. Safety rounds were documented in 24% of local cases versus 31% nationally.

Conclusion: While the project showed strong performance in falls assessment and mitigation, there were notable gaps in delirium screening and initiation of CGA. These findings highlight areas for targeted improvement to optimise care for older adults in the ED setting.

Keywords— delirium screening, falls risk assessment, frailty in older adults, emergency department quality improvement.

Pre-operative Screening and Optimization for Orthopedics Elective Surgery

Hana Rashid, Lingham Aranghan, Ahmed Hafaz, Woojae, Mr. Kantak

Abstract—

Introduction: With a growing, older, multi-morbid population, complications from elective orthopedic surgery are unfortunately a routine and increasing part of surgical practice. National standards based on robust evidence (1) recommend pre-operative optimisation (obesity, smoking, exercise, alcohol, diabetes, frailty, anaemia, etc) to substantially reduce the risk of operative complications. The project aimed to evaluate the current practice of pre-operative screening and management of risk factors for patients undergoing elective TKR, THR, and Spine Decompression surgery. Following GIRFT, 7 top interventions(2), our project aiming at complication reduction, smoother recovery.

Methods: Over 7 months period, data collected for elective total knee replacement (TKR), total hip replacement (THR), and spine decompression surgery. Patients were randomly selected from hospital records. For each patient, surgeons' clinic letters, pre-assessment clinic letters, and joint school assessments were reviewed. We recorded whether the surgeon had screened for pre-operative risk factors including lifestyle factors (smoking, obesity, exercise, alcohol moderation, nutrition, mental wellbeing) and medical conditions (opioid use, COPD/OSA, anaemia, atrial fibrillation, diabetes, frailty, hypertension), and whether any intervention was provided (e.g., smoking cessation advice, weight management support, medical optimization, referral to primary/secondary care, social prescribing). It also assessed whether the patient in pre-assessment clinic has screened for lifestyle and medical risk factors and whether THR and TKR patients were assessed according to joint school guidelines.

Results: Screening in the pre-assessment clinic (PAC) was high for TKR (92%) and THR (100%) but lower for spine patients (88%). Joint school assessment was completed for all TKR and THR patients but none of the spine patients. Smoking was the most frequently documented lifestyle factor, identified in 42% of TKR, 36% of THR, and 13% of spine patients. Alcohol was recorded in 33% of TKR, 27% of THR, and 13% of spine patients. Obesity was specifically documented in 27% of THR patients but not in TKR or spine patients. Among medical risk factors, hypertension was the most commonly documented (33% TKR, 73% THR, 13% spine), followed by diabetes mellitus (17% TKR, 36% THR, 13% spine). Other conditions such as COPD, OSA, and AF were identified rarely. A significant gap was observed between the identification of risk factors and documentation of interventions. Of patients with at least one risk factor, interventions were recorded in 33% of TKR, 64% of THR, and 38% of spine patients. Most interventions were documented in the pre-assessment clinic (PAC) with few in surgical clinics or joint school assessments letters.

Conclusion: While pre-operative screening is routinely performed, there is inconsistent documentation of specific lifestyle and medical risk factors. Most significantly, there is a gap in intervention, where a high proportion of identified risks do not have a corresponding management plan documented. These findings highlight an opportunity to improve pre-operative optimisation through better documentation and more consistent referral or intervention pathways.

Keywords— preoperative optimization, elective orthopaedic surgery, risk factors, perioperative care, documentation, intervention gap, total joint arthroplasty.

Comparing Tension Band Wiring Using K-wires and Cannulated Screws in Transverse Patella Fracture Fixation

Lina Chevalier, Mohammed Yassin, Rory Middleton

Abstract— Transverse patella fractures are routinely fixed using tension band wiring (TBW) with Kirschner wires and cerclage band. The aim of this study was to compare the outcomes of the traditional technique against the more recent use of cannulated screws with fibre tape in a figure of 8.

We performed a retrospective cohort study of all the surgically fixed patella fractures from 2020 to 2025 at the Royal Cornwall Hospital. The patients were divided in two groups: TBW group and cannulated screws group. The primary outcome measured was failure of fixation and the need for removal of metal work.

An overall 56 patients with patellar fractures were included in this study. TBW were used for 24 (42.9%) patients and cannulated screws in 32 (57.1%) cases. There were three incidents of metal work failure in the TBW and none in the cannulated screws group. 11 (45.8%) patients in the TBW group needed symptomatic metal work removed whilst this was required in 8 (25%) patients in the cannulated screw group.

We observed a low rate of fixation failure in both groups. Symptomatic implants – the most common complication observed – was higher in the TBW group in our practice. Despite limited numbers in each group of patients, the hope of this study is to shine the light on the use of cannulated screws for patella fractures. This may reduce the need for a second operation, and ultimately, the load on the already stretched services.

Keywords— knee surgery, patella fixation, tension band wiring, trauma, fibretape.

Relevance of Pre-Discharge Blood Test and Radiographs After Elective Hip and Knee Arthroplasty in ASA 1 & 2 Patients – We May Not Always Need Them

O. Ayodabo, L. Chevalier, G. Irpati, C.K. Chuen, M. R. Norton, W. E. Jewell, R. G. Middleton

Abstract— Blood tests and radiographs are routinely performed after joint arthroplasty. However, evidence to their necessity is sparse. Recent advances in enhanced recovery pathways and day-case arthroplasty emphasise an evidence-based and standardised approach. This study aims to explore a sub-group of fitter patients for whom these tests might not be mandatory.

We undertook a retrospective study of 612 ASA 1 and 2 patients post total hip or knee arthroplasty. Patient details and blood results were obtained from electronic and paper medical records. Return to theatre and alterations of rehabilitation were matched to post-operative radiographs.

We reviewed a total of 612 patients, 92.2% were in the ASA 2 and 7.8% in the ASA1 category. The average age was 67.9 ± 10.2 years, with a M:F ratio of 0.8:1. The main finding was a relatively low number of abnormal post-operative blood test result, 59(9.6%), with only 6.7% of all patients receiving specific interventions. A total of 42 patients had post-operative haemoglobin <100 g/l, 4 of these were symptomatic needing treatment. Acute kidney injury was seen in 13 patients, 11(85%) of these with pre-existing renal disease; all were in the ASA 2 category and remained asymptomatic. Four patients had electrolyte abnormalities, 2 each with hyponatraemia <125 mmol/L and hypokalaemia <3 mmol/L. There was no abnormal post-operative radiography that altered management.

Our findings suggest that blood tests may not always be necessary in a select group of ASA 1/2 patients with normal pre-existing blood tests, provided they remain asymptomatic in the post-operative period and with no other safety concerns. We can also conclude that if there is no surgical concern, it is safe to delay post-operative radiography.

Keywords— Hip and knee arthroplasty, ASA 1 and 2, Post-operative Hb, eGFR, Radiographs.

National Spot Audit of Dislocated Hemiarthroplasty Management (SAD Hemi)

Ahmed Mostafa, Lina Chevalier, Ciaran Brenan, Mohammed Haruna, Rory Middleton

Abstract—

Introduction: Hip Hemiarthroplasty is common for treating hip fractures in the elderly, but dislocation, though rare, carries a high mortality rate of 30-57%. Limited guidance exists, with one study suggesting revision arthroplasty after an unsuccessful reduction. However, a recent audit indicates the Peterborough Protocol may cause unnecessary revisions, increasing morbidity, mortality, and costs. As hip fractures rise globally, more dislocations are expected. Effective management requires broad data analysis, as unit-level data alone is inadequate. A more comprehensive treatment approach is necessary.

Aim: The aim of this work is to establish a national collaborative to assess current practices for managing hip hemiarthroplasty dislocations, compare these practices with the Peterborough protocol, and ultimately develop an updated protocol or guideline for optimal management.

Methods: This national retrospective service evaluation will analyse patients aged 60 or older who presented with hip hemiarthroplasty dislocations between January 1, 2015, and December 31, 2020, across secondary care hospitals in the UK. The study will include both conservatively and operatively managed dislocations, excluding patients under 60 and those with associated proximal femoral periprosthetic fractures. Data will be collected from the National Hip Fracture Database and other relevant hospital records. The outcomes will assess the prevalence of dislocations, timing, demographic profiles, management pathways, and final outcomes, with a comparison of the Peterborough Protocol to national data. **Results:** Data from 7 sites on 157 patients revealed 115 eligible individuals with an average age of 83.5 years, 67% female, and 72.7% had posterior dislocations. Most hemiarthroplasties followed the anterolateral approach, in line with NICE guidelines. The study showed a higher success rate with closed reductions compared to the Peterborough protocol, with fewer conversions to THR or Girdlestone procedures. Mortality was high, with a 76% mortality rate at the time of study entry, higher than for non-dislocated hemiarthroplasty patients.

Conclusion: The data suggests the Peterborough protocol, which recommends conversion to THR after the first or second dislocation, may need reconsideration. While more data is needed to draw further conclusions, the current dataset from five sites already provides three times more information than any previous study.

Keywords— hip dislocation, hip hemiarthroplasty, management, peterborough protocol.

Hip Resurfacing Makes for Easier Surgery with Better Functional Outcomes at Time of Revision - A Case Controlled Study

Ahmed Mostafa, Lina Chevalier, M. R. Norton, R. G. Middleton

Abstract—

Background: Revision total hip arthroplasty (THA) is known to be a challenging procedure with potential for poor outcomes. Due to its lack of metaphyseal encroachment, hip resurfacing arthroplasty (HRA) is classified as a bone conserving procedure. Although the literature postulates that this is an advantage at time of revision surgery, there is no evidence to either support or refute this claim.

Methods: It identified 129 hips that had undergone HRA and 129 controls undergoing first revision THA. It recorded the clinical assessment and survivorship of implants in a multi-surgeon, single centre, retrospective case control series for both arms. These were matched for age and sex. Data collected included demographics, indications for surgery, Oxford Hip Score (OHS), length of surgery, length of hospital stay, blood transfusion, implant complexity and further surgical procedures. Significance was taken as $p < 0.05$.

Results: Mean follow up was 7.5 years (1 to 15). There was a significant 6 point difference in postoperative OHS in favour of the revision resurfacing group ($p=0.0001$). The revision HRA group recorded 48 minutes less length of surgery ($p<0.0001$), 2 days less in length of hospital stay ($p=0.018$), a reduced need for blood transfusion ($p=0.0001$), a need for less complexity in revision implants ($p=0.001$) and a reduced probability of further surgery being required ($P=0.003$).

Conclusion: Whilst we acknowledge the limitations of this study our results suggest that, in contrast to THA, the bone conservation element of HRA may make for a less traumatic revision procedure with better functional outcomes. Use of HRA has seen a dramatic decline as a result of concerns regarding metallosis. However, this information remains of relevance when counselling young active patients about their arthroplasty options and may become pertinent in the future if the promise of ceramic hip resurfacing is ever realised.

Keywords— hip resurfacing, revision, total hip arthroplasty, total hip replacement.

Dynamic Hip Screw Plate System: Clinical Follow-up to Provide Safety, Performance and Clinical Benefits Data

AME Mostafa, J Young, L Chevalier, RG Middleton

Abstract—

Introduction:

Femoral neck fractures are common injuries with a high morbidity and mortality rate.

Surgical management is the current gold standard (DHS)

Aim:

To provide data on the clinical outcome of the Zimmer DHS plate system

Methods:

Zimmer DHS Plate System at the Royal Cornwall Hospital.

Retrospective data was analysed according to three categories:

- Safety (complication incidence)
- Clinical (surgical data)
- Performance (OHS)

Results:

- 120 patients were included.
- Mean op duration was of 64.1 minutes
- Mean LOS 9.82 days
- Complications were 12 (1 device-related)

Surgical approach had an effect on surgical and clinical outcome. Per-vastus approach resulted in reduced OP duration and LOS, fewer complications and better OHS when compared to sub-vastus approach (Table 1).

Patient outcome is affected by fracture classification, with end OHS increasing from 31-a1 fractures to 31-b3 fractures. Despite having a higher proportion of fracture classifications with a poorer outcome, per-vastus approach still gave a better outcome than sub-vastus approach, hence the benefit of per-vastus approach may be greater than these results suggest.

Conclusion:

The Zimmer DHS plate system is an effective method of fixation of femoral neck and stable proximal femur fractures. Per-vastus surgical approach results in reduced operation duration, fewer complications during surgery, reduced length of hospital stay and higher OHS on follow up. This may result in better patient outcome although further studies accounting for cofounders are needed.

Keywords— Dynamic hip screw fixation, DHS, Neck of femur fracture, Subvastus approach.

Divers' influence on student Social Anxiety: Evidence from the Pakistani Universities

Muhammad Waheed, Attia Siddique

Abstract—The objective of this study is to examine the variables that affect students' social anxiety in Narowal, Punjab, Pakistan. Social Anxiety influenced by the Physical Exercise, Social Support, Expressive Suppression, Sports Self-Efficacy. Questionnaires were used as part of this study's quantitative methodology. We have received 378 complete, accurate, and useful surveys. To analyze the data, SPSS (26.0) software was utilized. Multiple regression analysis and Pearson correlation were employed to analyze the data. Physical exercise, social support, expressive suppression, and sports self-efficacy all significantly reduce social anxiety, according to the empirical results. The social support has the highest contribution (sig. = 0.000, $t = 6.510$, $\beta = 0.832$). The results of this study revealed that physical exercise had a significant negative direct effect on social anxiety (sig. = 0.000, $t = -7.789$, $\beta = -0.309$). Student's expressive suppression conduct is highly impacted by their social anxiety (sig. = 0.000, $t = 9.051$, $\beta = 0.415$). sport self-efficacy conduct is negative impacted by their social anxiety (sig. = 0.000, $t = -4.368$, $\beta = -0.540$).

Keywords—Social anxiety, physical exercise, social support, expressive suppression, sports self-efficacy.

I. INTRODUCTION

THE term "social anxiety" describes an overt and intense dread of being embarrassed or receiving a poor grade in social situations [1]. In addition to negatively affecting a person's studies, life, and typical social interactions, social anxiety can exacerbate other mental illnesses, which can significantly impair a person's quality of life as well as their health. It ranks third in terms of causes of sickness, behind alcoholism and depression. In addition to coping with the psychological effects of identity change, college students in the adaptive transition stage from adolescence to adulthood must effectively manage the demands of multiple facets while juggling their studies, personal lives, and interpersonal relationships [2]. Additionally, the many social evaluation problems that college students face may increase their likelihood of experiencing imagined or actual shame anxieties, which can result in frequent feelings of social anxiety [3]. Relevant polls indicate that between 10 and 33% of college students have social anxiety symptoms, and that number is rising year [4].

Exercise's ability to lower social anxiety while boosting psychological resilience and self-efficacy is becoming more widely acknowledged. According to studies, social anxiety symptoms can be effectively reduced by engaging in sports like baseball and sand play [5]. The psychological mechanisms at play, however, are yet unknown. Based on other studies, we

suggest that expressive repression and sports self-efficacy are important mediators between physical activity and social anxiety. The confidence in one's capacity to participate in physical activities, or sports self-efficacy, is essential for coping mechanisms and emotional control [6]. Teenagers who have higher levels of athletic self-efficacy are more confident in social settings and use coping strategies like social support and cognitive reappraisal, which lessen social anxiety [7].

The methods by which people exercise control over the incidence, severity, and expression of their emotions are known as emotion regulation techniques [8]. Expressive suppression, which usually appears in the latter phases of the emotional process, is a crucial emotion management technique according to Gross's theory of emotion regulation. It primarily reduces imminent or active emotional manifestations, which attenuates the subjective experience of emotion. Expressive suppression is connected to mood disorders including anxiety and sadness and a range of psychological suffering [9]. People who suffer from mood disorders frequently show increased degrees of expressive repression. On the other hand, increased in social anxiety is associated with expressive suppression, which is the deliberate repression of emotional expression. Social anxiety may worsen in those who often repress their feelings because they may become more distressed and engage in avoidant actions. Research shows that prolonged social anxiety symptoms are associated with an over-reliance on expressive repression [10]. Exercise and social anxiety may be mediated by expressive suppression because of its function in emotion control.

College students' anxiety levels have been sharply rising [11]. According to the findings of a research on college students' mental health, 42% of students reported feeling anxious to some extent as the pandemic expanded. Anxiety symptoms affect over 20.6% of Chinese college students [12]. 18.2% of college students experienced symptoms of anxiety during the pandemic [13]. College students are in a key stage of cognitive, emotional, social, and psychological development as they go from youth to adulthood. Thus, college students' primary source of worry is their thoughts about their future lives and careers. The difficulties and demands that today's college students must deal with are growing daily due to the complexity of societal variables. Anxiety is growing more common among college students, which means that if it is not controlled with the right strategies, it will interfere with their everyday lives, their academic performance, and maybe even the way their personalities develop. Thus, investigating practical strategies to

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reduce anxiety is a pressing area of research for us right now.

Pakistani college students' psychological well-being is currently being studied using cross sectional data to clarify patterns and causal links. In addition to showing that psychological issues such as stress, depression, and anxiety in college students are dynamic processes that differ among different groups, this also emphasizes how important components like social sport and self-esteem are in addressing these psychological issues. In order to shed light on the ways that physical activity supports teenage mental health, this study intends to investigate these psychological processes. The results might aid in the development of treatments by educators, coaches, and mental health specialists that support better emotion management techniques and increase self-efficacy.

II. LITERATURE REVIEW

Social Anxiety

Social anxiety is defined as intense and persistent discomfort or fear in social events or public settings, which frequently leads to avoidance behaviors. Research on the impact of physical activity on social anxiety symptoms has yielded conflicting results. According to the stress-buffering theory, positive variables can mitigate the effects of external stressors. The extreme fear of rejection or embarrassment by others is known as social anxiety [14]. In order to prevent possible rejection, socially anxious people may repress the expression of their emotional feelings. The less emotion that is shown, the less stuff that might be rejected by others. According to Kashdan and Steger [15], "[socially anxious people] lessen the possibility that they will make a serious social mistake that results in outright rejection by not genuinely expressing themselves."

Suppression and Social Anxiety

People's and their relationships' wellness is often compromised when negative emotions are suppressed. Yet, since people frequently suppress their negative feelings to preserve intimate relationships, expressive suppression may occasionally be harmless [16]. This may be particularly true when expressive suppression is used by those who display heightened negative emotion expressions, such as those with high levels of attachment anxiety. There is growing evidence that the repression of emotional expression is, in fact, linked to social anxiety. An interpersonal style that avoids showing emotion, for instance, is linked to social anxiety [14]. Furthermore, compared to people with generalized anxiety and a non-clinical control group, socially anxious people expressed fewer happy feelings [17]. Despite reporting higher levels of anger than participants in the community control group, those with social anxiety disorder also reported stronger repression of their anger [18]. So, the following hypothesis is proposed:

- H₁: Expressive Suppression has influence on social anxiety.

Social Support and Social Anxiety

Social support is the assistance that people receive from the outside world to help them deal with stress. According to Lubis et al. [19], social support is the assistance that people receive

from the outside world to help them deal with stress. There are many different types of social support, such as peer, familial, financial, and spiritual support. People who have a high degree of social support are more likely to have great self-confidence, be inspired to deal with life's challenges in a reasonable manner, and engage in productive activities [20]. According to pertinent research, social support has a significant role in enhancing a person's impression of their control over circumstances. According to the definition, social anxiety is mostly caused by uncontrollability and a negative assessment of environmental changes, and people can overcome this anxiety with the significant assistance of perceived social support [21]. Family members, friends, and other people may provide psychological support to college & university students, and this kind of assistance can help them deal with social anxiety. So, the following hypothesis is proposed:

- H₂: Social support has influence on social Anxiety.

Physical Exercise and Social Anxiety

Students' mental health may be effectively promoted by physical activity, which also helps to reduce social anxiety. Social anxiety among students is influenced by a number of intricate elements. Prior research has mostly examined and studied how social anxiety is influenced by personal cognitive characteristics including peer connections and subjective well-being. Despite the importance of these aspects, a flexible and workable solution is not possible. This somewhat restricts how far the research findings may be used. But an increasing number of academics have realized that concentrating just on how individual cognitive characteristics affect social anxiety is insufficient. Physical activity can satisfy people's basic psychological needs and raise their cognitive level to ensure the development of their mental health, according to the social cognitive behavioral model and self-decision-making theory. Physical activity reduces social anxiety by promoting positive emotions and releasing negative ones. This offers strong evidence that physical activity can reduce social anxiety externally. So, the following hypothesis is proposed:

- H₃: Physical exercise has influence on social anxiety.

Social Support and Social Anxiety

Social support is the assistance that people receive from the outside world to help them deal with the stress they face. There are many different types of social support, such as peer, familial, financial, and spiritual support. People who have a high degree of social support are more likely to have great self-confidence, be inspired to deal with life's challenges in a reasonable manner, and engage in productive activities. social exchanges [22]. According to pertinent research, social support has a significant role in enhancing a person's impression of their control over circumstances [23]. According to the definition, social anxiety is mostly caused by uncontrollability and a negative assessment of environmental changes, and people can overcome this anxiety with the significant assistance of perceived social support [21]. Furthermore, one study found that people who had less social support are more prone to experience anxiety and sadness [24]. So, the following

hypothesis is proposed:

- H₄: Social Support has influenced on social anxiety.

This study uses the following theoretical model and a quantitative methodology to assess theories and variables. This

model shows how the influence expressive suppression, social support, physical exercise and sports self-efficacy toward social anxiety.

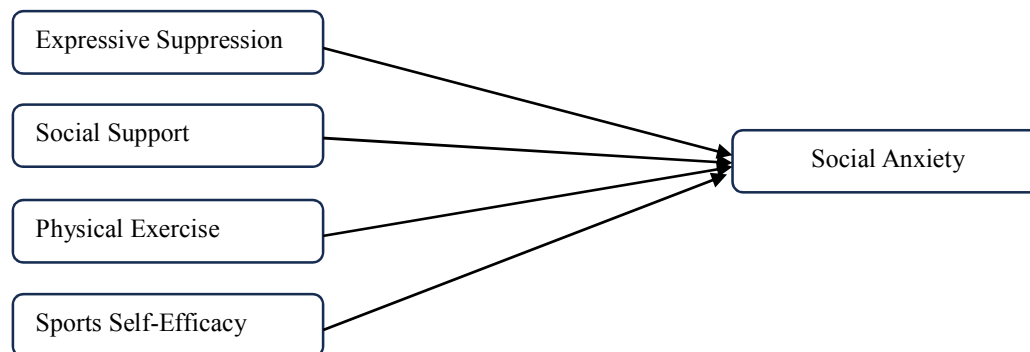


Fig. 1 Conceptual model

III. RESEARCH METHODOLOGY

To accomplish its goals, the present study employed a cross-sectional survey research design. According to Fink [25], the intent of the survey technique is to gather data on people's attitudes, behaviors, and knowledge. A survey approach is the ideal choice if information on people's attitudes, behaviors, and knowledge is needed. Therefore, a survey approach seemed most appropriate for the goals of the present study. A purposive sampling technique was used in this study to choose its participants. The target population is the undergraduate and graduate students of Narowal.

The scales used to measure the variables in this study were divided into two portions and had previously been created in the literature. Section B assesses expressive suppression, social support, physical exercise and sports self-efficacy toward social anxiety, whereas Section A gives a summary of the demographic traits of male and female students. The measurement scales of social anxiety were adopted from the research of Nelemans et al. [26]. The measurement scales of expressive suppression were adopted from the research of Gross and John [27]. The measurement scales of physical exercise were adopted from the research of Benmaamar et al. [28]. The measurement scales of Social Support were adopted from the research of Zimet et al. [29]. The measurement scales of sports self-efficacy were adopted from the research of Polizzi et al. [30]. The researcher used a 5-point Likert scale, with choices ranging from strongly disagree to strongly agree, to assess the participants' answers. Using a questionnaire, the researcher gathers information from the students. 400 students were given surveys, but 378 replies were gathered; of these, 22 were not fully completed, yielding 378 fully completed questionnaires.

After entering the detailed data from all 378 respondents into SPSS, the individual data were examined on a group basis. In terms of mean, skewness, kurtosis, maximum, and minimum, descriptive statistics provide information on the degree of expressive suppression, social support, physical exercise, and

sports self-efficacy toward social anxiety. To investigate the link between the variables, this study employed the regression test, Pearson correlation, and Cronbach's Alpha analysis.

IV. RESULTS

TABLE I
PROFILE OF SAMPLE

Sample characteristics	Categories	Frequency
Gender	Male	145
	Female	233
	18-22	90
Age (years)	22-26	170
	26-30	85
	30-40	15
	Over 40	18
	Bachelors	285
Level of education	Master	70
	M.Phil or Above	23

Normality Test

TABLE II
DESCRIPTIVE STATISTICS

	SA	PE	SS	ES	SSE
N	378	378	378	378	378
Skewness	-.635	.263	-.580	-.020	-.081
Kurtosis	-1.319	-1.793	-1.450	-1.771	-1.716
Minimum	1.00	1.00	1.00	1.00	1.00
Maximum	5.00	5.00	5.00	5.00	5.00

Note: SA = Social Anxiety, PE = Physical Exercise, SS = Social Support, ES= Expressive Suppression, SSE = Sports Self-Efficacy.

Researchers use the normality test to determine whether or not all of the data are normally distributed. The findings of this study indicate that all variables' skewness values fall within the range of ± 1 . Kurtosis results indicate that all variables have values within the range of ± 3 . As a result, the findings demonstrate that the data is normally distributed.

Reliability Analysis

The reliability test is a consistent technique that allows

researchers to quickly assess the trustworthiness of data. The "SPSS" test uses Cronbach's Alpha, which has a relative standard of 0.70, indicating reliability.

TABLE III
RELIABILITY STATISTICS

Construct	Cronbach's Alpha
Social Anxiety	0.769
Physical Exercise	0.725
Social Support	0.790
Expressive Suppression	0.756
Sports Self-Efficacy	0.829

Table III demonstrates the Cronbach's alpha values for expressive suppression, social support, sports self-efficacy, physical exercise, and social anxiety is 0.756, 0.790, 0.725, 0.829, and 0.769 respectively. The data and variables can be regarded as having sound reliability because the values are greater than 0.70.

Correlation Analysis

The method of analyzing or evaluating the relationship between variables is correlation. The relevance and strength of the link between two variables will be shown by the Pearson correlation.

TABLE IV
CORRELATION STATISTICS

Constructs	SA	PE	SS	ES	SSE
SA Correlation	1				
PE Correlation	-.692**	1			
SS Correlation	.789**	-.531**	1		
ES Correlation	.753**	-.524**	.677**	1	
SSE Correlation	.690**	-.505**	.653**	.965**	1

**. Correlation is significant at the 0.01 level (2-tailed).

Note: SA = Social Anxiety, PE = Physical Exercise, SS = Social Support, ES = Expressive Suppression, SSE = Sports Self-Efficacy

1. Social Anxiety and Physical Exercise

A correlation analysis was used to assess the relationship between social anxiety and physical exercise. With a value of -0.692, the analysis's findings revealed a negative moderate strong association between the two variables. Furthermore, the link was shown to be statistically significant at the significance level of 0.01. It means that if the level physical exercise increases, then social anxiety level decreases.

2. Social Anxiety and Social Support

A correlation analysis was used to assess the relationship between social anxiety and social support. With a value of 0.789, the analysis's findings revealed a strong association between the two variables. Furthermore, the link was shown to be statistically significant at the significance level of 0.01. It means that if the level social support increases, then social anxiety level increase.

3. Social Anxiety and Expressive Suppression

A correlation analysis was used to assess the relationship between social anxiety and expressive suppression. With a value of 0.753, the analysis's findings revealed a strong association between the two variables. Furthermore, the link

was shown to be statistically significant at the significance level of 0.01. It means that if the level expressive suppression increases, then social anxiety level increase.

4. Social Anxiety and Sports Self-Efficacy

A correlation analysis was used to assess the relationship between social anxiety and sport self-efficacy. With a value of 0.690, the analysis's findings revealed a strong association between the two variables. Furthermore, the link was shown to be statistically significant at the significance level of 0.01. It means that if the level Sport Self-Efficacy increases, then social anxiety level increase.

Regression

TABLE V
MODEL SUMMARY

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.892 ^a	.796	.791	.57241

a. Predictors: (Constant), PE, SSE, ES, SS

As shown in Table 4.5 above, the R square is 0.796, indicating that expressive repression, social sport, physical exercise, and sports self-efficacy all have a 79.6% impact on social anxiety among Narowal teenagers. However, the size of the residue coefficient $(100-79.6) = 20.4$ was clarified by other factors that were not part of the model.

TABLE VI
ANOVA^a

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	248.707	4	62.177	189.763	.000 ^b
1 Residual	63.893	195	.328		
Total	312.600	199			

a. Dependent Variable: SA

b. Predictors: (Constant), PE, SSE, ES, SS.

According to Table 4.6 above, the F-test portion of the ANOVA analysis has a value of 189.763, which is significant at the 0.000 level. Therefore, the overall regression model for expressive suppression, social sport, physical exercise, and sports self-efficacy captures the variations in social anxiety among Narowal students.

TABLE VII
REGRESSION COEFFICIENT

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.996	.208		9.607	.000
	PE	-.277	.036	-.309	-7.789	.000
	ES	.394	.044	.415	9.051	.000
	SS	.790	.121	.832	6.510	.000
	SSE	-.509	.117	-.540	-4.368	.000

The regression equation of the influence of expressive suppression, social support, physical exercise, and sports self-efficacy on social anxiety may be stated as follows, based on the analysis results in Table 4.7:

$$\text{Social Anxiety (Y)} = -0.309 \text{ physical exercise} + 0.415 \text{ expressive suppression} + 0.832 \text{ Social Support} - 0.540 \text{ Sport}$$

Self-efficacy

Table 4.7 shows that students physical exercise conduct is highly impacted by their social anxiety (sig. = 0.000, $t = -7.789$, $\beta = -0.309$). The findings show that, when all other factors are held constant, a one unit rise in physical exercise would result in a 0.309 decrease in social anxiety of the students. Also, Table 4.7 demonstrates that that student's expressive suppression conduct is highly impacted by their social anxiety (sig. = 0.000, $t = 9.051$, $\beta = 0.415$). The findings show that, when all other factors are held constant, a one unit rise in expressive suppression would result in a 0.415 increase in social anxiety of the students.

Table 4.7 shows that students social support conduct is highly impacted by their social anxiety (sig. = 0.000, $t = 6.510$, $\beta = 0.832$). The findings show that, when all other factors are held constant, a one unit rise in social support would result in a 0.832 increase in social anxiety of the students. Also, Table 4.7 demonstrate that that student's sport self-efficacy conduct is negative impacted by their social anxiety (sig. = 0.000, $t = -4.368$, $\beta = -0.540$). The findings show that, when all other factors are held constant, a one unit rise in sport self-efficacy would result in a -0.540 decrease in social anxiety of the students.

This study analyzes the influence of expressive suppression, social support, physical exercise, and sports self-efficacy towards social anxiety. Theoretically, it expands on studies on exercise-induced psychological resilience. In practice, social anxiety is directly decreased by regular exercise, while social adaptation is indirectly improved by increasing sports self-efficacy and maybe reducing expressive repression [31].

This study consistent with previous research is showing that physical activity significantly and adversely predicts teenage social anxiety [32]. By highlighting how exercise improves cognitive assessment and contextual adaptation, it confirms the use of Social Cognitive Theory in adolescent mental health. Frequent exercise enhances emotional states, physical fitness, and self-confidence which lowers social anxiety [33].

V. CONCLUSION AND LIMITATIONS

This study highlights the significant influence of physical exercise, expressive suppression, social support, and sport self-efficacy on social anxiety. The results suggest that increased physical activity and higher sport self-efficacy are associated with lower levels of social anxiety, indicating their protective and empowering roles. Conversely, greater reliance on expressive suppression and higher perceived social support were linked to increased social anxiety, revealing the potential complexity in how individuals manage emotions and seek interpersonal support.

To the best of our knowledge, this study is the first to look at the relationship between students' expressive suppression, social support, sports self-efficacy, and physical exercise, and social anxiety symptoms. There are a few restrictions to take into consideration. Since this study was cross-sectional, it is impossible to rule out reverse causality. The findings of this article require validation through other cohort studies. Second,

as there were no objectively measured data available, all factors were self-reported, making it impossible to prevent social desirability bias and recall bias.

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