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Academic Journal

— Volume 12, 2025 —



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Welcome to the twelfth volume of Seven Bridges, Newcastle College University Centre's (NCUC) multi-disciplinary academic journal. This volume is an exemplification of the attentiveness and commitment of all individuals involved, showcasing the excellent research being conducted by the students at NCUC.

The completion of the Seven Bridges journal demonstrates NCUC's principle of 'Students in Partnership'. Behind every student, there is a team of people supporting them and helping make this journal a reality. From lecturers to academic coaches, the student editorial team to the research and student engagement team, students' research is continuously developed and encouraged. This includes ensuring students' academic writing skills are refined and polished, their work is peer reviewed and the logistics are facilitated. All of this allows for students to flourish and enables the production of the Seven Bridges journal to continue year on year.

In this volume, you can expect to find a variety of studies, covering themes ranging from storing energy in infrastructure to aesthetic medicine. A massive thank you to all of the authors, and we hope you enjoy reading!

Dionne, Eleanor and Laura

Seven Bridges Editorial Board

# Structural Supercapacitors: Electrifying the Road to Net Zero

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## ABSTRACT

*To support the United Kingdom's (UK) sustainability goals, there must be serious consideration as to how renewable energy storage and delivery can be optimised. One solution that is emerging in the literature is utilising building materials to create structural supercapacitors. By implementing energy storage into construction materials, structural supercapacitors are not only set to utilise existing infrastructure but decarbonise the material industry by supporting renewable energy sources. Current literature surrounding structural supercapacitors recognises the technology's strengths in supporting electricity delivery to off-grid locations, however some studies also highlight that the energy density of these materials needs to be optimised to meet household energy demand. Furthermore, several practical and ethical issues with the technology also remain, including human rights issues that surround material mining and compromises between structural integrity and electro-density. Despite identified areas for improvement, overall, the principal of structural supercapacitors shows promise in supporting the road to Net Zero.*

**KEYWORDS:** Energy, Structural Supercapacitors, Net Zero, Concrete.

## INTRODUCTION

Within the UK Government's roadmap to achieve Net Zero by 2050, there are several proposals of decarbonisation mechanisms, with a large proportion focussing on increasing the sustainability of both domestic dwellings and transport. One of the eventualities proposed within the Net Zero Strategy policy was the replacement of traditional fossil fuel heating systems with those that use electricity from renewable sources. However, one of the biggest obstacles, highlighted within the policy, is the increase in capacity required in the national grid system before total electrification of such systems can become an actuality (Department for Energy Security and Net Zero and Department for Business, Energy & Industrial Strategy, 2021). Chanut *et al.* (2023) concur, stating that the largest challenge when transitioning from conventional fossil fuel energy at national scale, is the demand for bulk renewable energy storage systems. Due to the inconsistency of energy generation indicative of renewable sources, for example wind turbines when wind speeds are minimal, there are requirements for a large storage solution where supply can sufficiently cater to demand if the implementation of such power sources is to be successful (Chanut *et al.*, 2023). However, availability of minerals used in the production of present-day energy storage systems, for example batteries, is rapidly declining. The decline of such minerals therefore limits the potential for these

current technologies to be used in bulk energy supply. Research investigating bulk energy storage systems that are cost-effective and utilise globally abundant materials have led to the development of structural supercapacitors (Chanut *et al.*, 2023).

Structural supercapacitors are defined as energy storing systems that collate the porous, high surface area (Chanut *et al.*, 2023) of load bearing existing structural materials, such as concrete, with the electrochemical efficiency of the conventional supercapacitor. This in turn creates a high performing energy storage and supply mechanism, within a space optimising and lightweight system, ideal for application within the electrification of both the domestic and automobile sector (Zschiebsch *et al.*, 2024). This report will discuss recent developments within the structural supercapacitor field in further detail.

### LITERATURE REVIEW

One of the key benefits that structural supercapacitors bode is the potential to act as large-scale energy storage systems within the renewable energy sector. By supporting the renewable sector, structural supercapacitors offer vast environmental benefit whilst also supporting energy self-sufficiency, particularly in rural domestic dwellings (Hatzfeld *et al.*, 2022). The research conducted by Hatzfeld *et al.* (2022) explores the idea of inserting structural supercapacitors within holders into buildings and analysing the environmental impact via life cycle assessment (LCA). By aiding storage of renewable energy this would act as an offset for any greenhouse gas emissions caused by the production of structural supercapacitors. The idea of inserting structural supercapacitors into already existing dwellings would decrease any additional carbon footprint caused by manufacturing entirely new concrete systems (Hatzfeld *et al.*, 2022), such as the electrical vehicle charging roadways suggested by Chanut *et al.* (2023). The LCA carried out by Hatzfeld *et al.* (2022), is a useful tool in assessing the suitability of structural supercapacitors, mainly focussing on the potential for global warming, as it features the key values of the UK Government's Net Zero strategy (Department for Energy Security and Net Zero and Department for Business, Energy & Industrial Strategy, 2021). However, within new and emerging technologies, it is necessary to consider that an assessment on environmental impact on a developing process is subject to change. Therefore, feasibility and development studies of the actual system should be determined initially, by wider literature reviews or experimental reports with standardised metrics, so that the data can be compared in an unbiased manner (Greenhalgh *et al.*, 2023).

IEA (2021) predict increased mineral demand for the next two decades, driven by the call for cleaner technologies, which will include the use of supercapacitors for domestic and industrial energy. Within the predictions, it is estimated that based on mass, the largest demand for minerals will be that of graphite, nickel and copper, all substituents within electrical energy storage technologies (IEA, 2021). Therefore, due to the scarcity of the natural resources needed to produce lithium-ion batteries, existing energy storage technologies have limited application in domestic dwellings. However, on the contrary, selection of materials to produce supercapacitors is extensive (Hatzfeld *et al.*, 2022). Furthermore, the materials available to manufacture structural supercapacitors specifically are in wider abundance. Research conducted by Chanut *et al.* (2023) features electrodes that are produced using cement, carbon

black and water, hailing them some of the most readily available resources worldwide. However, with the increased worldwide uptake of battery technologies, carbon black can prove an expensive resource. Therefore, some literature explores replacing some of the material with carbon fibres as a cost-saving alternative (Zhang and Tang, 2021), which will be a key consideration during the scale-up process.

An influential factor on material demand for structural supercapacitors is the fundamental design of these energy storage systems, which varies throughout the literature. Hatzfeld *et al.* (2022) suggest that a viable design is that of a plastic holder structure containing the supercapacitors that is inserted into the carbon reinforced concrete of a wall. This principle differs from other research within this field, as the supercapacitor is inserted into the structure within a holder, without it being integrated within the concrete structure itself. This is a huge advantage, as it mitigates the demand for extensive new building materials, whilst also allowing removal of the supercapacitor element if required without the need for whole building demolition (Hatzfeld *et al.*, 2022). Much of the literature, however, focusses on a concrete integrated electrification system. Although using concrete integrated electrification technology generally requires larger amounts of material, the quantities used within these systems can differ, dependant on manufacture processes. Within research into concrete batteries, Zhang and Tang (2021) compare the difference in electrochemical performance when using two varying manufacturing techniques and material levels. One structure dispersed the active metal materials into the cement to create the anode and cathode, whereas the other coated the actives onto a mesh system to create the two electrodes. The battery which featured the coated mesh system and therefore used more materials, performed more successfully within the cyclic analysis (Zhang and Tang, 2021).

Differences emerged within the literature regarding the experimentation methods used. Although many of the papers use the conventional battery analysis techniques such as looking at cyclic charge-discharge (Chanut *et al.*, 2023; Zhang and Tang, 2021), not all featured mechanical analysis, which is a critical success metric in structural supercapacitors. All the papers discussed featured structural supercapacitors made from carbon-reinforced traditional building materials such as cement (Zhang and Tang, 2021). In using cement this would suggest that structurally these supercapacitors would have high load bearing capabilities, however without sufficient mechanical testing the suitability for application is unknown. Ensuring that the structural supercapacitor is structurally sound, increases possible applications. For example, Hatzfeld *et al.* (2022) discuss the possibility that if suitable, a structural supercapacitor could be integrated into the floor of a driveway to potentially support the charging of electrical vehicles.

The Department for Energy Security and Net Zero (2023) release annual consumption tables on the average electrical energy expenditure from UK homes. In 2023, it was reported that on average each domestic household used a total of 3408 kWh throughout the year (Department for Energy Security and Net Zero, 2023). The reported average house size in England and Wales in 2020 was 99 m<sup>2</sup> (Office for National Statistics, 2020). Therefore, based on average residence size and energy usage, structurally integrated electrical storage with an energy

density of 34.42 kWhm<sup>2</sup> would be required to power a dwelling for a year. Zhang and Tang (2021) reported an average energy density of a rechargeable concrete battery produced with nickel and iron to be 0.0068 kWhm<sup>2</sup>, which is significantly lower than that of a conventional lithium-ion battery and therefore does not yet meet requirement.

## ETHICS

There are several competing ethical factors when considering the technology of structural supercapacitors. These include efficiency versus environmental impact, but also structural integrity versus efficiency. Chanut *et al.* (2023) found that higher water to cement ratios within structural supercapacitors yielded the highest energy storage, however this also led to the lowest structural hardness measurement, a finding that Greenhalgh *et al.* (2023) also reported. This raises the moral issue of potentially using lesser mechanically integral structural materials to increase electrical energy efficiency. Similarly, Hatzfeld *et al.* (2022) reported that larger supercapacitor panels within buildings would increase energy per area. However, their research also highlighted that larger panels would require increased quantities of materials to manufacture. Therefore, this would present the difficult task of ensuring that the global warming potential from the increased material demand, would not undermine the sustainability benefit of the final technology.

Zhang and Tang (2021) describe the principle of creating structural supercapacitors as adding active metals to building materials such as concrete to create energy storage. Therefore, even though structural capacitors offer a host of environmental advantages and climate change offsets, they do not mitigate the need for the supply of metals conventionally used in batteries, such as lithium. The recycling of batteries and other energy devices to obtain these key metals is not yet advanced enough to maintain the demand needed for the uptake of cleaner energy solutions, therefore traditional mining techniques are and will be required for the foreseeable future (Niri *et al.*, 2024). The continuation of these traditional techniques presents several social and ethical issues, including child labour and exploitation, risks to worker and surrounding communities' health and corruption. To tackle these issues and make the resourcing of key elements more sustainable within the structural supercapacitor sector, there needs to be fundamental change throughout all levels of the mineral supply chain, which could present a challenge (Niri *et al.*, 2024).

In 2021, National Statistics (2022) reported that 14.7 % of vehicles newly registered that year were electrically powered. With Chanut *et al.* (2023) suggesting that one of the applications for electrified concrete being highways that will charge electrical vehicles as they travel, this raises the question of whom will front the cost for this development. As part of Net Zero by 2050, the UK government have made financial provisions for similar changes to take place to infrastructure, but not on this scale (Department for Energy Security and Net Zero and Department for Business, Energy & Industrial Strategy, 2021). One funding possibility may be an increase in vehicle and local council tax to cover the transformation and upkeep of the new electrified roads; however, this would need to be fairly applied. For example, applying

vehicle tax increases only to those who will benefit from these developments such as those with electric vehicles.

There are also safety considerations when introducing structural supercapacitors to domestic dwellings. Greenhalgh *et al.* (2023) highlight the potential issues of moisture exposure in structural supercapacitor manufacture, which would also apply once the technology is introduced to infrastructure. Effective weather proofing and safety features would need to be considered and applied to buildings with electrified structural materials, to mitigate system damage but also hazards such as electrocution.

## CONCLUSION

Within the last three years, research into structural supercapacitors and the benefit they could offer to future energy supply has increased and continues to do so. Experimental data from the literature is promising, supporting that in principle structural supercapacitors could be used to store and provide energy. However, as discussed above, serious development work will have to be undertaken to compete with existing technology, create a suitable level of electrical supply (Zhang and Tang, 2021) and support structural supercapacitor scale up (Greenhalgh *et al.*, 2023).

This development work would need to have several key considerations, not least of which; cost and safety of implementing the mechanism into domestic properties, industrial buildings, and highways. It is also key, that within future research, a more succinct series of analytical measurements is developed for research to be compared and evaluated effectively (Greenhalgh *et al.*, 2023). The technology sector would also benefit from an increase in objective research, as it was observed within the literature review that several current publications are funded by specialist organisations within the field.

With all the development points taken into consideration, it can be concluded that the role of structural supercapacitors will be imperative in the successful implication of the UK Government strategy to achieve Net Zero by 2050 (Department for Energy Security and Net Zero and Department for Business, Energy & Industrial Strategy, 2021).

## Reference List

Chanut, N., Stefaniuk, D., Weaver, J., Zhu, Y., Shao-Horn, Y., Masic, A., Ulm, F J. (2023) 'Carbon-cement supercapacitors as a scalable bulk energy storage solution', *Proceedings of the National Academy of Sciences of the United States of America*, 32(120), pp.1-7.

Department for Energy Security and Net Zero (2023) *ECUK 2023: Consumption data tables (Excel)* [online]. Available at: <https://www.gov.uk/government/statistics/energy-consumption-in-the-uk-2023> (Accessed: 15 April 2024).

Department for Energy Security and Net Zero and Department for Business, Energy & Industrial Strategy (2021) *Net Zero Strategy: Build Back Greener* [online]. Available at: <https://www.gov.uk/government/publications/net-zero-strategy> (Accessed: 2 April 2024).

Greenhalgh, E S., Nguyen, S., Valkova, M., Shirshova, N., Shaffer, M S P., Kucernak, A R J. (2023) 'A critical review of structural supercapacitors and outlook on future research challenges', *Composites Science and Technology*, (235), pp.1-19.

Hatzfeld, T., Schlüter, D., Scope, C., Krois, K., Guenther, E., Etzold, B., Curbach, M. (2022) 'Rethinking residential energy storage: GHG minimization potential of a Carbon Reinforced Concrete facade with function integrated supercapacitors', *Building and Environment*, (224), pp.1-12.

IEA (2021) *The Role of Critical Minerals in Clean Energy Transitions*. Paris : IEA [online]. Available at: <https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions/mineral-requirements-for-clean-energy-transitions> (Accessed : 3 April 2024).

National Statistics (2022) *Vehicle licensing statistics: 2021* [online]. Available at: <https://www.gov.uk/government/statistics/vehicle-licensing-statistics-2021/vehicle-licensing-statistics-2021#new-electric-vehicle-registrations> (Accessed: 15 April 2024).

Niri, A J., Poelzer, G A., Zhang, S E., Rosenkranz, J., Pettersson, M., Ghorbani, Y. (2024) 'Sustainability challenges throughout the electric vehicle battery value chain', *Renewable and Sustainable Energy Reviews*, (191), pp.1-15.

Office for National Statistics (2020) *About the size of a London flat* [online]. Available at: <https://blog.ons.gov.uk/2020/02/21/about-the-size-of-a-london-flat/#:~:text=Here%20at%20the%20ONS%20we%E2%80%99ve%20been%20exploring%20the,%28sqm%29%20%E2%80%93%20that%E2%80%99s%20about%20nine%20typical%20parking%20spaces> (Accessed: 15 April 2024).

Zhang, E Q., Tang, L. (2021) 'Rechargeable Concrete Battery', *Buildings*, 11(3), pp.1-14.

Zschiebsch, W., Sturm, Y., Kucher, M., Hedayati, D P., Behnisch, T., Modler, N., Böhm, R. (2024) 'Multifunctionality Analysis of Structural Supercapacitors – A Review', *Materials* 2024, 17(3), pp.1-27.

# An Experiment to Introduce a STOP Codon to the LacZ Gene in *Escherichia coli* (*E. coli*) HB101-pBRKan using Clustered Interspaced Short Palindromic Repeat (CRISPR)

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## ABSTRACT

*This experiment highlights the methods and results of introducing a STOP codon into the LacZ gene of E. coli HB101-pBRKan using CRISPR-Cas9 technology. The study aims to disrupt the function of LacZ and visually confirm the gene editing through colour changes. The methodology focuses on the transformation of LacZ, deoxyribonucleic acid (DNA) extraction and analysis via polymerase chain reaction (PCR) and gel electrophoresis. Despite contamination in one plate due to technical limitations, the results demonstrated successful gene editing in some samples. This study highlights the potential of CRISPR for genomic modifications and the results suggest improvements in aseptic techniques to enhance reliability. While the technology shows promise for therapeutic applications, including cancer treatment, further technical and ethical considerations are necessary for its advancement.*

## KEYWORDS

CRISPR, DNA extraction, gene editing, homology directed repair, polymerase chain reaction.

## INTRODUCTION AND LITERATURE REVIEW

CRISPR and the CRISPR-Cas genes comprise part of an adaptive immune defence system, located in approximately 95 % of archaeal genomes and 48 % eubacterial genomes, used to protect archaea and bacteria from invading viruses (Bondy-Denomy et al., 2015; Silva et al., 2023; Ogrodzki and Forsythe, 2016; Golkar, 2020). Bacteria use this system to breakdown viral DNA and memorise the bacteriophage DNA pre-empting further infection (Hermel et al., 2023). The bacterial strain in this experiment is *E. coli* HB101-pBRKan. Kanamycin is included on all plates to remove any bacteria that are not the specific strain of *E. coli*. CRISPR is in this strain by previous engineering to express the Cas9 enzyme and plasmid carrying genes that enable homology directed repair (HDR) enzymes controlled by arabinose (Bio-Rad Laboratories, Inc., 2022).

Essential proteins, single guide ribonucleic acid (sgRNA) and Cas-9, are used in the CRISPR/Cas-9 system (Asmamaw and Zawdie, 2021). Cas-9, a sequence-specific DNA-

targeting protein originating from *Streptococcus pyogenes*, has been engineered to respond to specific nucleic acids (Jin et al., 2019; Uddin et al., 2020). Cas-9 is directed to the gene of interest by the designed sgRNA through complementary base pairing. The Cas-9 nuclease breaks double-stranded DNA in specific locations (Asmamaw and Zawdie, 2021). These locations are decided via the protospacer adjacent motif (PAM), a short signature sequence that varies in accordance with each CRISPR-based system (Shah et al., 2013). To cut the specific sequence of DNA, it must lie at the 3' end of the sgRNA, the PAM, then is repaired via two potential pathways. First, a non-homologous end joining which leads to random insertion or deletion of DNA. Second, HDR, where a homologous section of DNA is used as a template, allowing precise genome editing (Redman et al., 2016).

CRISPR has wide reaching applications including the potential to inactivate tumour suppressor genes, editing oncogenes or disease genes through HDR (Mou et al., 2017). The method is highly desirable as it has the potential for precise and permanent targeting of mutations and the targeting of small non-coding ribonucleic acid (RNA) (Hussen et al., 2023). Also, CRISPR-Cas9 has advantages over other gene editing therapies such as a higher gene-editing efficiency and no unwanted DNA integration (Yang and Yang, 2022; Xiaoshuai et al., 2022). The CRISPR-Cas9 system is highly effective due to its ability to precisely modify targeted genomic regions by altering only 20 nucleotide sequence within the sgRNA and therefore enhances its versatility (Sato and Kuroda, 2023). However, sgRNAs can induce exon skipping or delete exons which could lead to unexpected outcomes such as apoptosis rather than the intended gene edit (Uddon et al., 2020; Mou et al., 2017).

Despite the potential for positive therapeutical applications, there are limitations to CRISPR-Cas9, both technically and ethically. One technical concern is the off-target effects in complex eukaryotic organisms, in vivo. The specificity of the target depends upon off-target cleavage of the genome and the sgRNA of Cas9 and PAM sequences. Although editing programs can identify potential off-target genome cleavages, they are limited to examining homologous genes (Yang et al., 2021). Further limitations include the requirement for a PAM sequence near the site to be targeted, Cas9 is large and difficult to package into adeno associated viral vectors and CRISPR/Cas9 raises concerns for immunogenic toxicity (Uddon et al., 2020). Prior to the procedure being released into the medical community, the technical limitations need to be overcome. However, due to rapid advancements, this may be achieved. Ethically, the effect of modified organisms is difficult to determine in future generations, further complicating the moral decision making. Finally, due to genetic information related to biological phenotypes not being fully understood, the consequences of editing a gene in somatic or germline cells are unclear. It is difficult to design a biological phenotype at the whole-organism level without the knowledge of the contribution of environmental, epigenetic factors and biological phenotype (Brokowski and Adli, 2018).

This experiment aims to evaluate the process of CRISPR in the disruption to LacZ function and visualise the results. This report details the methodology, interpretations, and recommendations for the experiment to introduce a STOP codon to the LacZ gene using

## METHODOLOGY

Two starter plates are set up prior to this experiment and inoculated with *E. coli* HB101-pBRKan bacteria as shown in **table 1**.

Starter Plate	Plate Additives	Bacterial Colony Colour	Cas9	DNA Repair System	sgRNA	Donor Template DNA
IX	IPTG, X-gal, LB, Kanamycin	Blue	+	OFF	-	-
IX/ARA	IPTG, X-gal, Arabinose, LB, Kanamycin	Blue	+	ON	-	-

Table 1. Starter plate conditions; Isopropyl 6-D-1-thiogalactopyranoside (IPTG), 5-bromo-4-chloro-3-indoyl-6-D-galactopyranoside (X-gal), Lysogeny broth (LB)

Four 2.0 mL microcentrifuge tubes are labelled A-D and placed on ice. 250 µL of ice-cold transformation solution (TS) is pipetted into each tube and the tubes are placed back on ice. Five colonies are taken using an inoculation loop from the IX plate and dispersed into the TS solution of tube A and then repeated for tube B. With a new loop, five colonies from the IX/ARA plate and dispersed into the TS solution of tube C and repeated in tube D. 10 µL pLZDonor (pD) plasmid is pipetted into tube A and the solution is mixed by flicking the tube, then placed on ice. This is repeated with a new pipet tip for tube C. 10 µL pLZDonorGuide (pDG) plasmid is pipetted into tube B, mixed, and placed on ice. This is repeated to tube D with a fresh pipet tip. The tubes are incubated on ice for 10 minutes switching to a water bath at 60 °C for 50 seconds then, immediately returning the tubes to ice for 2 minutes. After placing the tubes back to room temperature, 250 µL of LB nutrient broth is pipetted into each tube, and each tube is flicked to mix the solution. After 20 minutes at room temperature, the bacterial growth is efficient to start the next stage of the test. Four agar plates, impregnated with IX/Spectinomycin are labelled A-D. Tube A is flicked gently to resuspend the bacteria before 100 µL of sample A is transferred onto plate A. The sample is spread evenly on plate A using a fresh inoculation loop. This process is repeated using fresh pipet tips and inoculation loops, for samples B-D. The final plate setup is shown in **table 2**.

Plate	Starter Plate	Plate Additives	Cas9	DNA Repair System	sgRNA	Donor Template DNA
A	IX	IPTG, X-gal, Spectinomycin, LB, Kanamycin	+	OFF	-	+
B			+	OFF	+	+
C	IX/ARA	Kanamycin	+	ON	-	+
D			+	ON	+	+

Table 2. The final plate conditions

The plates are then covered, stacked, taped, and incubated at 37 °C upside-down to avoid condensation affecting results. After a week, the incubated plates are checked for colour development in the colonies. Results are recorded by counting the blue and white colonies for each plate by dividing the plates into quadrants.

The next stage in this experiment involves the extraction of genomic DNA from the bacteria. Five screw-cap tubes are labelled with S, C, D1, D2 and D3. The InstaGene Matrix (IG) is resuspended evenly and 250 µL is pipetted into each tube. A single blue colony is chosen from the IX/ARA plate using the end of a pipet tip and swirled in the tube labelled S to disperse the bacteria. For the tube labelled C, a fresh pipet tip was used to select a single blue colony of bacteria from the C plate and dispersed into the tube. A single white colony is chosen from plate D with a new pipet tip and dispersed into the tube labelled D1, this is repeated for the tubes labelled D2 and D3 with fresh pipet tips each time. The tubes are then vortexed for 10 seconds to mix and incubated in a water bath at 56 °C for fifteen minutes. The tubes are then vortexed again and incubated in a dry bath at 95 °C for eight minutes before leaving to slightly cool and using the vortex to mix again. The tubes are centrifuged at 12000 x g for two minutes. PCR tubes are labelled S, C, D1, D2, D3, (+) and (-). 10 µL of the master mix primers are pipetted into each PCR tube, followed by 10µL of supernatant from each of the respective five screw cap tubes. A new tip is used to pipet 10 µL of the positive PCR control DNA to the (+) tube. A new tip is used to add 10 µL of the negative PCR control into the tube labelled (-). The tubes are capped and placed into the thermal cycler with the program identified in **table 3**. The PCR involves the denaturation, annealing and amplification of DNA. Denaturing allows hydrogen bonds to break in the double-stranded DNA to allow primers, during the annealing process, to bind to the single stranded DNA beginning at the 3' end of the template. Finally, the elongation of DNA is complete by DNA polymerase. The amplification technique denatures and renatures short segments of DNA to produce identical strands to be evaluated (Khehra et al., 2023).

Step	Temperature (°C)	Time (mins)	Cycles
Initial Denature	94	5	1x
Denature	94	0.5	
Anneal	62	0.5	35x
Extend	74	1	
Final Extension	74	5	1x
Hold	12	-	1x

Table 3. PCR thermal cycler run conditions

PCR samples are centrifuged in pulses to pull the contents to the bottom of each tube. 5 µL of loading dye is pipetted to each tube using a new pipet tip each time to mix the samples. 1 % Tris-acetate-EDTA (TAE) agarose gel is poured into the electrophoresis chamber, orientated so the wells are closest to the cathode. After the gel sets the chamber is covered in TAE electrophoresis buffer by approximately 2 mm. Samples are loaded into each well as shown in **table 4**.

Lane	Sample	Volume, µL
1	Molecular Weight Ruler (MWR)	15
2	Positive PCR Control (+)	15
3	PCR Sample (S)	15
4	PCR Sample (C)	15
5	PCR Sample (D1)	15
6	PCR Sample (D2)	15

7	PCR Sample (D3)	15
8	Negative PCR Control (-)	15

Table 4. Gel electrophoresis wells conditions

The lid is replaced on the electrophoresis chamber and the leads are connected to the power supply. The power is turned on and the gel is run at 5 V for 20 minutes. Gel electrophoresis separates DNA into different bands. DNA has a phosphate backbone with a negative charge. Therefore, DNA travels towards a positively charged electrode in an electric field. Due to a uniform charge/mass ratio, DNA is scattered over the gel in size order, with distance travelled inversely proportional to the log of its molecular weight (Lee et al., 2012). The gel is removed from the chamber and placed in a tray filled with a stain for five minutes. The gel is then removed, washed, and placed in a tray of water to remove further stain. The result from this gel shows bands of DNA.

## GENE EDITING RESULTS

The editing of *E. coli* bacteria produced visual results and numerical results as shown in **table 5**. Plate A's bacterial growth is shown in **figure 2**. Only blue colonies are identifiable on the plate indicating the bacteria has not been modified. There are no white colonies on plate A, resulting in 0 % white colonies. Plate B's bacterial growth is shown in **figure 3** and produced no growth indicating an environment not fit for reproduction. Plate C's growth is shown in **figure 4**. 100 % of the colonies are white on plate C, indicating the bacteria is modified and the LacZ gene is no longer active. Plate D's bacterial growth is shown in **figure 5** and produced only tiny white bacterial colonies. Therefore, D is modified successfully.

Plate	Blue Colonies	White Colonies	Total Colonies	% of White Colonies (%)
A	51	0	51	0
B	0	0	0	N/A
C	0	38	38	100
D	0	41	41	100

Table 5. Actual results of plates for the gene editing experiment

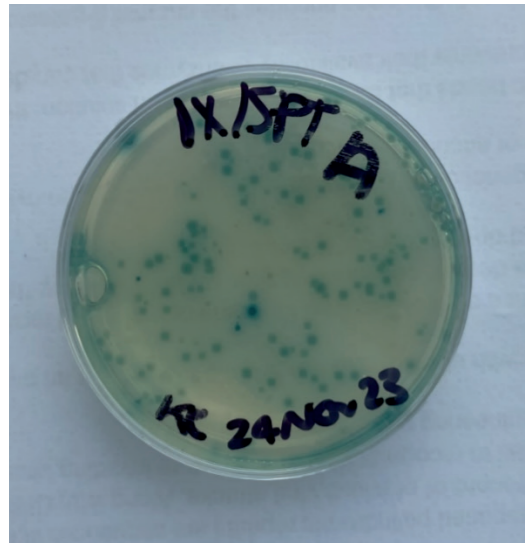


Figure 1. Plate A, actual results



Figure 2. Plate B, actual results



Figure 3. Plate C, actual results



Figure 4. Plate D, actual results

### PCR AND GEL ELECTROPHORESIS RESULTS

The result for the PCR and gel electrophoresis experiment is a visual representation. DNA is represented with different bands that are measured with amplicons to determine the LacZ gene status. To continue this experiment, a peer's blue colony from plate C is used for PCR sample C. In **figure 1** and **table 6**, the MWR, in column one produced a clear ruler to measure the other results against. The positive control shows bands at three identifying points on the MWR indicating the control has worked correctly. The PCR sample S, C, D1, D2 and D3 offers an amplicon result of 650 bp and 350 bp suggesting the LacZ gene is edited and the PCR control target is marked. The negative control in well eight produces a single band at 350 bp.

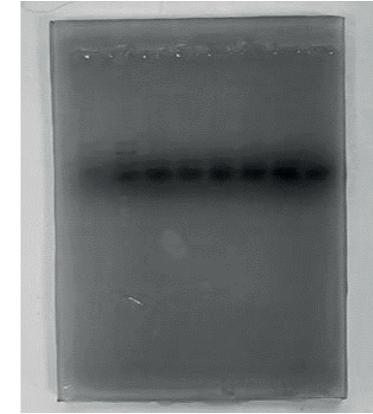


Figure 1: Results for gel electrophoresis

PCR Sample	1100 bp	650 bp	350 bp	LacZ gene status
MWR	Y	Y	Y	N/A
Positive Control (+)	Y	Y	Y	N/A
PCR Sample (S)	N	Y	Y	Edited
PCR Sample (C)	N	Y	Y	Edited
PCR Sample (D1)	N	Y	Y	Edited
PCR Sample (D2)	N	Y	Y	Edited
PCR Sample (D3)	N	Y	Y	Edited
Negative Control (-)	N	N	Y	N/A

Table 6. Actual results for PCR and gel electrophoresis samples

### INTERPRETATION AND EVALUATION

#### Gene Editing

Starter plates inoculated with *E. coli* are on two plates, IX and IX/ARA. The rich medium, LB agar, on each plate encourages highly reproducible results, fast growth, and good yields (Sezonov et al., 2007). IPTG is an efficient molecular inducer for regulating the lac promoter's transcriptional activity as a structural analogue of allolactose (Briand et al., 2016). LacZ codes for the enzyme  $\beta$ -galactosidase. The soluble colourless compound, X-gal, is hydrolysed by  $\beta$ -Galactose with the aid of an active  $\beta$ -galactosidase enzyme to produce the substituted indole that spontaneously dimerises into an insoluble, blue product (Juers et al., 2012). Therefore, the result of the successful insertion of the CRISPR-Cas9 system can be identified when X-Gal is not hydrolysed, and the blue is not present. Arabinose activates the HDR enzymes to repair the DNA in *E. coli* grown on the IX/ARA plate (Bio-Rad Laboratories, 2022). Each starter plate, therefore, starts with blue colonies as CRISPR has not genetically modified DNA.

Plate A-D are coated in LB, kanamycin, IPTG, X-gal and spectinomycin (SPT). Spectinomycin is a ribosome-binding antibiotic that blocks translocation in bacterial cells without a plasmid containing antibiotic resistant genes (Kanchugal and Selmer, 2020). *E. coli* that contains this plasmid will survive. Plate A contains bacteria from the IX starter plate and presents only blue colonies. Without the sgRNA in the pLZDonorGuide plasmid, the location the nucleases need to cut in the target DNA is not identified. The STOP codon for LacZ is not

inserted and therefore X-Gal hydrolyses as normal, creating blue product. Plate B is issued the sgRNA in the pLZDonorGuide plasmid and so allows the nucleases to cut the target DNA, making a double-stranded break, but lacks the activated repair machinery to perform HDR. This is due to the starter plate lacking arabinose to activate the repair system in *E. coli* bacteria. Therefore, *E. coli* does not repair the DNA and gain the spectinomycin resistance. The colonies collected for Plate C grow on plates with arabinose which activates the repair system enzymes. The results for plate C should produce only blue colonies as the sgRNA is not provided, as with plate A. However, the results show lots of white colonies on the plate in this experiment indicating a potential contamination with pLZDonorGuide. The white colonies demonstrate the gene editing to be successful, despite no guide RNA available purposely. Plate D contains colonies from the same starter plate and core plate additives as plate C but contains a pLZDonorGuide plasmid. The sgRNA allows the production of genetically modified white *E. coli* colonies with a series of steps. Firstly, the Cas9 system binds to the scaffold region of the sgRNA, which determines the structure. The Cas9-sgRNA complex binds to a PAM site on the target DNA (the Donor DNA template) and the guiding region of sgRNA binds to the target DNA sequence. Cas9 breaks the DNA base pairs upstream of the 5' PAM sequence. Finally, the complex releases the genetically modified DNA. The edited DNA includes a STOP codon for the LacZ gene and so,  $\beta$ -Galactose is not produced, resulting in no reaction with X-Gal. As this reaction normally causes a blue colour change, there is no colour change when it does not occur, making the colonies appear white (Bio-Rad Laboratories, Inc., 2022).

### PCR and Gel Electrophoresis

The PCR and gel electrophoresis is performed to discredit any potential off-target modifications that yielded the same result and any potential contamination of samples. For the PCR process, IG helps purify the DNA and contains Chelex resin. After autoclaving to obtain DNA, Chelex resin helps improve yield and efficacy as a PCR template. Although the mechanism of action of Chelex is not known completely, Alqahtani et al., (2020) suggests that Chelex may bind to and protect denatured single strand template DNA or protect metal ions from DNases.

After gel electrophoresis, the MWR offers a DNA ladder to compare unknown samples to. The mixture contains DNA fragments of pre-determined sizes and is used to determine the sample DNA fragments (Lee et al., 2012). The positive PCR control DNA fragments at 1100 bp, 650 bp and 350 bp. This control determines that, under the same conditions, if there is a positive result in the PCR sample, the bands will be produced. The positive control uses template DNA or primers known to amplify under the same conditions (Lorenz, 2012). PCR sample S and C do not follow the expected results, shown in **figure 8** and **table 7**, of 1100 bp and 350 bp, but instead appears as a modified version. This is potentially due to contamination of samples, the results being unclear and not leaving the gel long enough to spread. The dye was also dark around the results' area and needed longer to soak off. The PCR sample D1 to D3 show the modified LacZ gene with amplicons 650 bp and 350 bp. This is the same as the expected results. The negative control is contaminated due to an unexpected result with the amplicon, 350 bp. This may occur with leaking samples from the wells into

other wells which may have caused a band of protein to be produced. A negative control should not contain any of the DNA template and should have no bands appear on the gel electrophoresis. This rules out false positives and can be used to detect contamination as with this experiment (Chauhan, 2021).

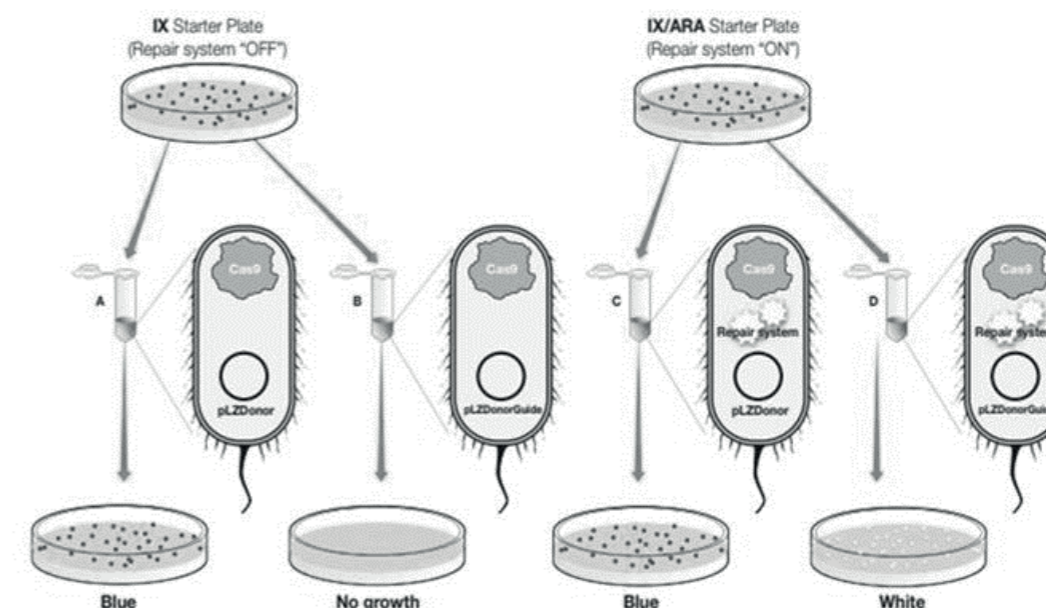


Figure 5. Experiment 1, gene editing, expected results

PCR Sample	1100 bp	650 bp	350 bp	LacZ gene status
MWR	Y	Y	Y	N/A
Positive Control (+)	Y	Y	Y	N/A
PCR Sample (S)	Y	N	Y	Wild type
PCR Sample (C)	Y	N	Y	Wild type
PCR Sample (D1)	N	Y	Y	Edited
PCR Sample (D2)	N	Y	Y	Edited
PCR Sample (D3)	N	Y	Y	Edited
Negative Control (-)	N	N	N	N/A

Table 1. PCR and gel electrophoresis expected results

### CONCLUSIONS AND RECOMMENDATIONS

To conclude, despite following the methodology, there is still place for errors. Therefore, there needs to be more aseptic technique applied to this experiment to reduce contaminations of samples. The experiment can be performed in a microbiological safety cabinet which is used to safeguard the product and environment (Pawar et al., 2021). Sterilised inoculating loops, instruments, solutions, and agar prior to plating reduces contamination between plates. Disinfecting the workbench to minimise external contamination and a Bunsen burner is a suitable alternative to the biological safety cabinet to create a convection current (Sanders, 2012). Contamination due to a lack of aseptic technique is the reason for plate C producing white colonies. The PCR results may have been the cause of contamination shown in the gel

electrophoresis and so should be repeated with care. Problems with PCR can result from poor primers and inconsistencies with ready-to-use mixes (Schrick and Nitsche, 2015). For the gel electrophoresis results, a more precise hand is needed to insert each sample into the gel. Deeper and further apart wells may help to contain all the sample and reduce the likelihood of samples mixing. Alternatively, higher performance equipment may reduce the risk of contamination between wells with more standardised approaches. This step would also need to be repeated with care and labelled correctly to determine the root cause. Overall, despite the issues shown in this experiment, CRISPR is a system with future applications in cancer biology, treatments of sickle cell anaemia and cystic fibrosis for example (Chekol et al., 2021). With more advancements in technology, financial investments, and an increase in understanding of genome editing, the adaptations of CRISPR aim to reach, once deemed, incurable diseases.

## REFERENCES

- Alqahtani, A., Skelton, A., Eley, L., Annavarapu, S., Henderson, D.J. and Chaudhry, B. (2020) 'Isolation and next generation sequencing of archival formalin-fixed DNA', *Journal of Anatomy*, 237(3), pp.587-600. Available at: DOI: 10.1111/joa.13209.
- Asmamaw, M. and Zawdie, B. (2021) 'Mechanism and Applications of CRISPR/Cas-9-Mediated Genome Editing', *Biologics*, 15, pp.353-361. Available at: DOI: 10.2147/BTT.S326422.
- Bio-Rad Laboratories, Inc. (2022) *Instructor Guide, Out of the Blue CRISPR Kit* [online]. Available at: <https://www.bio-rad.com/en-uk/product/out-blue-crispr-genotyping-extension-kits?ID=Q0JGD4E08O1Y#fragment-doc>. (Accessed: 02 January 2024).
- Bio-Rad Laboratories, Inc. (2022) *Student Guide, Out of the Blue CRISPR Kit* [online]. Available at: <https://www.bio-rad.com/en-uk/product/out-blue-crispr-genotyping-extension-kits?ID=Q0JGD4E08O1Y#fragment-doc>. (Accessed: 02 January 2024).
- Bondy-Denomy, J., Garcia, B., Strum, S., Du, M., Rollins, M.F., Hidalgo-Reyes, Y., Wiedenheft, B., Maxwell, K.L. and Davidson, A.R. (2015) 'Multiple mechanisms for CRISPR-Cas inhibition by anti-CRISPR proteins', *Nature*, 526(7571), pp.136-139. Available at: DOI: 10.1038/nature15254.
- Briand, L., Marcion, G., Kriznik, A., Heydel, J.M., Artur, Y., Garrido, C., Seigneuric, R. and Neiers, F. (2016) 'A self-inducible heterologous protein expression system in *Escherichia coli*', *Scientific Reports: Nature Research*, 6, pp.33037. Available at: DOI: 10.1038/srep33037.
- Brokowski, C. and Adli, M. (2018) 'CRISPR Ethics: Moral Considerations for Applications of a Powerful Tool', *Journal of Molecular Biology*, 431(1), pp.88-101. Available at: DOI: 10.1016/j.jmb.2018.05.044.
- Chauhan, T. (2021) *Type of PCR Controls – Negative, Positive and Internal Controls* [online]. Available at: [https://geneticeducation.co.in/type-of-pcr-controls-negative-positive-and-internal-controls/#Negative\\_control](https://geneticeducation.co.in/type-of-pcr-controls-negative-positive-and-internal-controls/#Negative_control). (Accessed: 03 January 2024).
- Golkar, Z. (2020) 'CRISPR: a journey of gene-editing based medicine', *Genes Genomics*, 42(12), pp.1369-1380. Available at: DOI: 10.1007/s13258-020-01002-x.
- Hermel, M., Lieberman, M., Slipczuk, L., Rana, J.S. and Virani, S.S. (2023) 'Monoclonal Antibodies, Gene Silencing and Gene Editing (CRISPR) Therapies for the Treatment of Hyperlipidemia—The Future Is Here', *Pharmaceutics*, 15(2), pp.459. Available at: DOI: 10.3390/pharmaceutics15020459.
- Hussen, B.M., Rasul, M.F., Abdullah, S.R., Hidayat, H.J., Faraj, G.S.H., Ali, F.A., Salihi, A., Baniahmad, A., Ghafouri-Fard, S., Rahman, M., Glassy, M.C., Branicki, W. and Taheri, M. (2023), 'Targeting miRNA by CRISPR/Cas in cancer: advantages and challenges', *Military Medical Research*, 10(1), pp.32. Available at: DOI: 10.1186/s40779-023-00468-6.
- Jin, M., Garreau de Loubresse, N., Kim, Y., Kim, J. and Yin, P. (2019) 'Programmable CRISPR-Cas Repression, Activation, and Computation with Sequence-Independent Targets and Triggers', *ACS Synthetic Biology*, 8(7), pp. 1583-1589. DOI: 10.1021/acssynbio.9b00141.
- Juers, D.H., Matthews, B.W. and Huber, R.E. (2012) 'LacZ  $\beta$ -galactosidase: structure and function of an enzyme of historical and molecular biological importance', *Protein Science*, 21(12), pp.1792-1807. DOI: 10.1002/pro.2165.
- Kanchugal, P.S. and Selmer, M. (2020) 'Structural Recognition of Spectinomycin by Resistance Enzyme ANT (9) from *Enterococcus faecalis*', *Antimicrobial Agents, and Chemotherapy*, 64(6), pp.e00371-20. Available at: DOI: 10.1128/AAC.00371-20.
- Khehra, N., Padda, I.S. and Swift, C.J. (2023) *Polymerase Chain Reaction (PCR)*. Treasure Island (FL): StatPearls Publishing.
- Lee, P.Y., Costumbrado, J., Hsu, C.Y. and Kim, Y.H. (2012) 'Agarose gel electrophoresis for the separation of DNA fragments', *Journal of Visualized Experiments*, (62), pp.3923. Available at: DOI: 10.3791/3923.
- Lorenz, T.C. (2012) 'Polymerase chain reaction: basic protocol plus troubleshooting and optimization strategies', *Journal of Visualized Experiments*, (63), pp.3998. Available at: DOI: 10.3791/3998.
- Mou, H., Smith, J.L., Peng, L., Yin, H., Moore, J., Zhang, X-O., Song, C-Q., Sheel, A., Wu, O., Ozata, D.M., Li, Y., Anderson, D.G., Emerson, C.P., Sontheimer, E.J., Moore, M.J., Weng, Z. and Xue, W. (2017) 'CRISPR/Cas9-mediated genome editing induces exon skipping by alternative splicing or exon deletion', *Genome Biology*, 18, pp.108. DOI: 10.1186/s13059-017-1237-8.
- Ogrodzki, P. and Forsythe, S.J. (2016). 'CRISPR-cas loci profiling of *Cronobacter sakazakii* pathogens', *Future Microbiology*, 11(12), pp. 1507–1519. Available at: DOI: 10.2217/fmb-2016-0070.
- Pawar, S.D., Khare, A.B., Keng, S.S., Kode, S.S., Tare, D.S., Singh, D.K., More, R.L. and Mullick, J. (2021) 'Selection and application of biological safety cabinets in diagnostic and

research laboratories with special emphasis on COVID-19', *The Review of Scientific Instruments*, 92(8), pp.081401. Available at: DOI: 10.1063/5.0047716.

Redman, M., King, A., Watson, C. and King, D. (2016) 'What is CRISPR/Cas9?', *Archives of Disease in Childhood - Education and Practice*, 101(4), pp.213-215. Available at: DOI: 10.1136/archdischild-2016-310459.

Sanders, E.R. (2012) 'Aseptic laboratory techniques: plating methods', *J Vis Exp*, (63), pp.e3064. Available at: DOI: 10.3791/3064.

Sato, G. and Kuroda, K. (2023) 'Overcoming the Limitations of CRISPR-Cas9 Systems in *Saccharomyces cerevisiae*: Off-Target Effects, Epigenome, and Mitochondrial Editing', *Microorganisms*, 11(4), pp.1040. Available at: DOI: 10.3390/microorganisms11041040.

Sezonov, G., Joseleau-Petit, D. and D'Ari, R. (2007) '*Escherichia coli* Physiology in Luria-Bertani Broth', *Journal of Biotechnology*, 189(23), pp.8746-8749. Available at: DOI: 10.1128/JB.01368-07.

Shah, S.A., Erdmann, S., Mojica, F.J. and Garrett, R.A. (2013) 'Protospacer recognition motifs: mixed identities and functional diversity', *RNA Biology*, 10(5), pp.891-899. Available at: DOI: 10.4161/rna.23764.

Silva, A.M.A., Luz, A.C.O., Xavier, K.V.M., Barros, M.P.S., Alves, H.B., Batista, M.V.A. and Leal-Balbino, T (2023). 'Analysis of CRISPR/Cas Genetic Structure, Spacer Content and Molecular Epidemiology in Brazilian *Acinetobacter baumannii* Clinical Isolates,' *Pathogens*, 12(6), pp.764. Available at: DOI: 10.3390/pathogens12060764.

Tiruneh, G., Medhin, M., Abebe, E.C., Sisay, T., Berhane, N., Bekele, T. and Dejenie, T.A. (2021) 'Current Applications and Future Perspectives of CRISPR-Cas9 for the Treatment of Lung Cancer', *Biologics*, 15, pp.199-204. Available at: DOI: 10.2147/BTT.S310312.

Uddin, F., Rudin, C.M. and Sen, T. (2020) 'CRISPR Gene Therapy: Applications, Limitations, and Implications for the Future', *Frontiers in Oncology*, 10, pp.1387. Available at: DOI: 10.3389/fonc.2020.01387.

Xiaoshuai, L., Qiushi, W. and Rui, W. (2022) 'Advantages of CRISPR-Cas9 combined organoid model in the study of congenital nervous system malformations', *Frontiers in Bioengineering – Biotechnology*, 10, pp.932936. Available at: DOI: 10.3389/fbioe.2022.932936.

Yang, Y., Xu, J., Ge, S. and Lai, L. (2021) 'CRISPR/Cas: Advances, Limitations, and Applications for Precision Cancer Research', *Frontiers in Medicine*, 8, pp.649896. Available at: DOI: 10.3389/fmed.2021.649896.

Yang, Y.C. and Yang, H.C. (2021) 'Recent Progress and Future Prospective in HBV Cure by CRISPR/Cas.' *Viruses*, 14(1), pp.4. Available at: DOI:10.3390/v14010004.

# How does Vygotsky's theories of ZPD and scaffolding influence reading development?

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## ABSTRACT

*This study primarily examines Vygotsky's theories of the Zone of Proximal Development (ZPD) and scaffolding, focusing on their influence on reading development. The perceptions of ZPD and scaffolding from different practitioners are gained through a self-completion questionnaire. The methods implemented within this study consist of qualitative and quantitative questions which links with the interpretivist research paradigm. Additionally, the data presented within the study supports the research questions, as the general consensus was that all participants found ZPD and scaffolding beneficial within their practice to support reading development in children.*

**KEYWORDS:** Vygotsky, ZPD, scaffolding, qualitative, quantitative.

## INTRODUCTION

Vygotsky's theories of Zone of Proximal Development (ZPD) and scaffolding have emerged as effective strategies to promote reading development in children. Margoli 2020 highlights the role of ZPD in education by stating that ZPD primarily focuses on a child's personality and way of thinking, instead of the traditional approach of memorising information that is instilled in schools. Furthermore, Gonzalez *Et al.* (2014; cited in Neumann, 2020) illustrated that scaffolding optimises children's reading development by encouraging them to achieve beyond age-based expectations. By combing both ZPD and scaffolding, research shows that children learn more effectively in relation to reading development.

The term ZPD was coined by Vygotsky (1978; cited in Khaliliaqdam, 2014) to refer to the extent in which a child can complete a task independently and with guidance. In relation to reading development, ZPD includes a more knowledgeable other (MKO) who models the knowledge to the child first, then provides guidance until the child can read independently (Ash & Levitt, 2003). Scaffolding, also coined by Vygotsky, can be defined as a MKO who provides their knowledge to a child and guides them to complete a task which expands the child's existent knowledge (Rogoff *Et al.* 1984). In addition, scaffolding, according to Cazden (1983; cited in Magno, 2010), refers to providing support with reading skills such as decoding. This insinuates that both ZPD and scaffolding are commonly used practices to support reading development.

By taking the background of the study into consideration, the central focus of this paper is to answer the following question, 'how does Vygotsky's theories of ZPD and scaffolding influence reading development?'. The primary aim of this paper is to explore the ways in which Vygotsky's theories influence reading development within modern curriculums such as the national curriculum.

The objectives that support the achievement of the aim relevant to the research questions include:

- To identify how Vygotsky's theories of ZPD and scaffolding influence reading development in the national curriculum.
- To compare and contrast participants perceptions of the effectiveness of Vygotsky's theories of ZPD and scaffolding in relation to reading development.

## LITERATURE REVIEW

### *Theoretical Underpinning*

There is a vast accumulation of literature that highlights the importance of Vygotsky's theories of scaffolding and ZPD, and their significance in reading development in young children. Mason & Sinha (1991) highlighted that Vygotsky's theories are within the social construction domain that focuses upon a MKO and how scaffolding offers support with children's reading development. By applying Vygotsky's social construct theories to reading development, evidence suggest that children's reading development is more efficient when a MKO provides scaffolding as Rose-Latson (2022) reported that students who had access to a MKO outperformed their peers by reading material that was four years advanced their current reading stage of development.

Vygotsky (1978, cited in Rose-Latson, 2022, pp. 33) claimed that the reason children were outperforming others within their ZPD, whilst an MKO was present, was due to them developing their true potential without the restraint of age-appropriate materials. It was acknowledged by Rose-Latson (2022) that some of the participants did not implement scaffolding into their practice. Therefore, it could be argued that the results gained from those individuals do not provide the same validity as others as they came from a hypothetical standpoint. Conversely, an alternate viewpoint depicted by Muzammil and Saifullah (2021) supports the hypothesis presented by Rose-Latson (2022), as they concur that students who are scaffolded by a MKO had a significant increase in reading comprehension scores. Together these studies provide important insights into the importance of a MKO in relation to reading development in children.

### *Strategies to support reading development*

Strategies to promote reading development are essential to use in schools. A recent study by Tajedini, Hashemzadeh and Sangari (2024) found that reading development strategies maintain interest in reading amongst children as it was implied that children often find difficulties with reading fatigue. By implementing strategies, children can read at a suitable pace. An example strategy is Accelerated Reader, which is a commonly used reading strategy within English schools. Accelerated Reader, created by Renaissance Learning in the 1980s, is

a computer-based reading development strategy. Renaissance (2024a) state that children are given a ZPD that provides them with a specific reading band suitable for their current level of reading. Renaissance (2024b) claim that they were influenced by Vygotsky's ZPD theory as it provides children an ideal range of books that are suitable for their current reading level. By applying ZPD to reading development, it could be suggested that children are provided with more accurate reading books that both interest and challenge them. Additionally, Accelerated Reader promotes children to read for pleasure, which is stated within the National Curriculum, therefore, this strategy supports the reading framework provided in the document.

## METHODOLOGY

### *Ontological Approach*

This paper will undertake an ontological approach which Ahmed (2008) defines as the nature surrounding a given social phenomenon and how individuals perceive it. The social phenomenon significant to this paper is reading development and how Vygotsky's theories of ZPD and scaffolding provide support to children. Frega (2018) argues that an ontological approach concerns the investigation of social interactions that establish societal concepts. In reference to the social phenomenon surrounding this study, the research proposes to uncover how reading materials support a child's reading development, as well as ascertain the social interactions between children's interest in reading with practitioners.

The ontological assumption underpinning the research is that there are multiple realities as Chalmers, Manley and Wasserman (2005; cited in Otoo, 2020, pp. 4) claim that a study can explore meanings within the realities through social interactions, which in this study is between the practitioner and the child, by using Vygotsky's theories to support reading development. The findings suggest that people see the world in different ways. This is due to their understanding of reality being shaped by their personal experiences and surroundings. This supports the idea that there is not a single, fixed version of reality, but a variety shaped by individual perspective. In the context of this study, responses could vary depending on where and how the research is carried out. A different setting might produce different results, simply because people interpret the world in different ways.

### *Research Paradigm*

The research paradigm adopted within this study is the interpretivist approach. The interpretivist paradigm, defined by Guba and Lincoln (1988; cited in Kivunja and Kuyini, 2017) is a philosophical way of understanding how humans interact within social contexts. Furthermore, Brundrett & Rhodes (2013) believe that researchers that use the interpretivism paradigm focus more on qualitative methods to collect data as, they elicit more rich and detailed responses from participants. This study will consist of mixed methods to ensure the best quality of responses are gathered to answer the research question. Both qualitative and quantitative data will be collected through a questionnaire provided to participants. Mixed methods, according to Almalki (2016) ensures, that all areas of the research questions provided will be answered to the highest degree of accuracy as both qualitative and quantitative data will be retrieved, offering both numerical and narrative feedback.

## METHODOLOGY

It was decided that implementing a mixed methods approach was the best method to adopt for this investigation. This decision is based upon the intention of receiving rich and detailed responses through qualitative questions as well as utilising a Likert scale to elicit clear opinions through numerical data.

### *Qualitative Methods*

Although mixed methods are employed within this study, a participatory qualitative research approach is the primary method. Due to the small-scale of the study, a quantitative based approach would not have been feasible as, insufficient data would be collected to provide accurate results to answer the research questions. Qualitative data reiterates the importance of understanding the meaning of experiences (Almalki, 2016) which is essential to this study as the meanings of the participants knowledge and experiences of Vygotsky's theories in relation to children's reading development are sought to answer the research question.

A qualitative research design is defined by Tenny, Brannan and Brannan (2022) as asking open ended questions to elicit rich responses personal to the participant. A benefit of using qualitative methods is to capture personal experiences and knowledge in a more accurate way. As this study relies on personal experiences, the questionnaire primarily consists of qualitative questions. The qualitative research design associated with this study is that it is emergent and evolving as the current understanding of reading development will change due to the responses collected being analysed and interpreted. This will create new meanings, contributing to what is known about reading development.

### *Quantitative Methods*

The quantitative method implemented in this study is two Likert scales on the questionnaire given to participants. They were included with the purpose of receiving an accurate representation of the participant's knowledge, experience and understanding of Vygotsky's theories, and how effective they perceive them to be in relation to reading development. A Likert scale helps to evade response set bias as the participants have no pressure to provide a specific answer, providing more personal and accurate responses. By combining a Likert scale with qualitative questions, the data should accurately gauge a meaningful perception from each participant, which will be analysed in response to the research question.

### *Sampling*

Stratton (2021) believes that sampling is a technique used within research to select participants who are relevant to the research study. Two types of sampling will be employed in this study, the first being convenience sampling. Convenience sampling, as defined by Obilor (2023) consists of a researcher intentionally choosing participants who are known, accessible and convenient. Convenience sampling is implemented in this study as all participants are known, providing a cost-effective way of obtaining responses.

The second sampling technique used is purposeful sampling. Purposeful sampling consists of strategically selecting participants based on their knowledge and experience with Vygotsky's

theories of ZPD and scaffolding (Palinkas *Et al*, 2013). Purposeful sampling is applicable to this research study as specific knowledge of Vygotsky's theories and individual perceptions are required to answer the research questions, presenting more accurate responses.

## DATA COLLECTION

This study utilises a qualitative data collection method as self-completion questionnaires are provided to the participants. Barrett and Twycross (2018) claim that qualitative data collection methods are beneficial as they provide an opportunity to explore individual perceptions to provide an insight into their practice, which was deemed the most appropriate collection method for the study.

## DATA ANALYSIS

Thematic analysis was employed in this study as it provides researchers with clear and cohesive data that is strategically split into themes that are gathered from reoccurrences in the responses (Wiltshire and Ronkainen, 2021). A theme is a reoccurring pattern that emerges from a data set that is linked to the research questions (Maguire and Delahunt, 2017)

This study will follow Braun and Clark's (2006) six steps to thematic analysis, as their guide provides simple phases to successfully break down data into themes. Themes will be made by correlating the data with the research questions. Once themes are decided, they will be named and reviewed to ensure that they are relevant to the research questions (*ibid*).

## LIMITATIONS

It is acknowledged due to the short time frame allocated to conduct the research; a larger scale study would be impractical. A small-scale research project is a limitation as the findings cannot be generalised to the rest of the populous. A small data set can produce an assumption of false premise, which does not reflect the wider society, where results may vary (Faber and Fonseca, 2014). This, therefore, cannot guarantee external validity. However, what a small data set can do is provide an insight into perceptions involving the research question.

Furthermore, internal validity associated with generalisation, according to Andrade (2018) concerns the examination of whether the research design and analysis truly reflect the research questions without bias. This study reflects internal validity as it is true to the setting in which the participants are employed. A true representation of the implementation of Vygotsky's practice will be reflected in this study as it is acknowledged that Vygotsky's theories of ZPD and scaffolding are implemented in the settings in which the participants work. This study aims to avoid bias by taking all responses at face value, and to analyse the data in relation to the research questions without personal bias. This will be achieved by directly quoting the respondents and analyse their responses with direct correlation to the research questions and the literature review. Within the literature review, researcher bias will be avoided by collating a vast number of sources with multiple perspectives to offer a holistic overview of the literature. Personal knowledge and opinions from the researcher will not be implemented to ensure that the study remains unbiased.

## ETHICS

Before conducting this study, ethical approval was granted by Newcastle College's ethics committee and BERA guidelines were followed. BERA (2024) outlines guidelines such as the right for all participants to withdraw at any time from research. BERA ensure that research is conducted without bias and discrimination to maintain dignity of everyone involved (ibid). It is stated within the document that researchers must be transparent with all participants about the study including whether their data may be subject to reuse (BERA, 2024). Informed consent was gathered from all participants before the data from the questionnaire was used within this study. It was clearly stated within the consent form and the gatekeeper letter that all participants have the right to withdraw before a certain date as data provided may still be used after that date, however it would remain anonymised. Complete transparency was provided to all participants before they agreed to be a part of the study. All participants remained anonymous, known as 'participant 1' for example.

## RESULTS

### *Theme 1: Strategies to support reading development*

#### *Modelling Behaviours*

The overall consensus was that all participants use scaffolding to provide guidance to the children. The key phrases that emerged from the data were 'modelling' and 'regular basis'. This suggests that reading to children on a regular basis is a scaffolding strategy to promote reading development. Participant 2 claims in their practice they focus on 'modelling and encouraging reading individually and in groups'. In addition, Participant 4 shares a similar perception that 'children are read to on a regular basis, and we have things in the classroom which helps the children to act out the story'. Taken together, these results suggest that scaffolding is a common practice to support reading development in children.

This section combines two questions within the questionnaire as one consisted of a Likert scale to gauge the participants personal beliefs on the effectiveness of ZPD, and a narrative question asking why they chose their answer. Figure 1 below displays the bar graph derived from the responses.

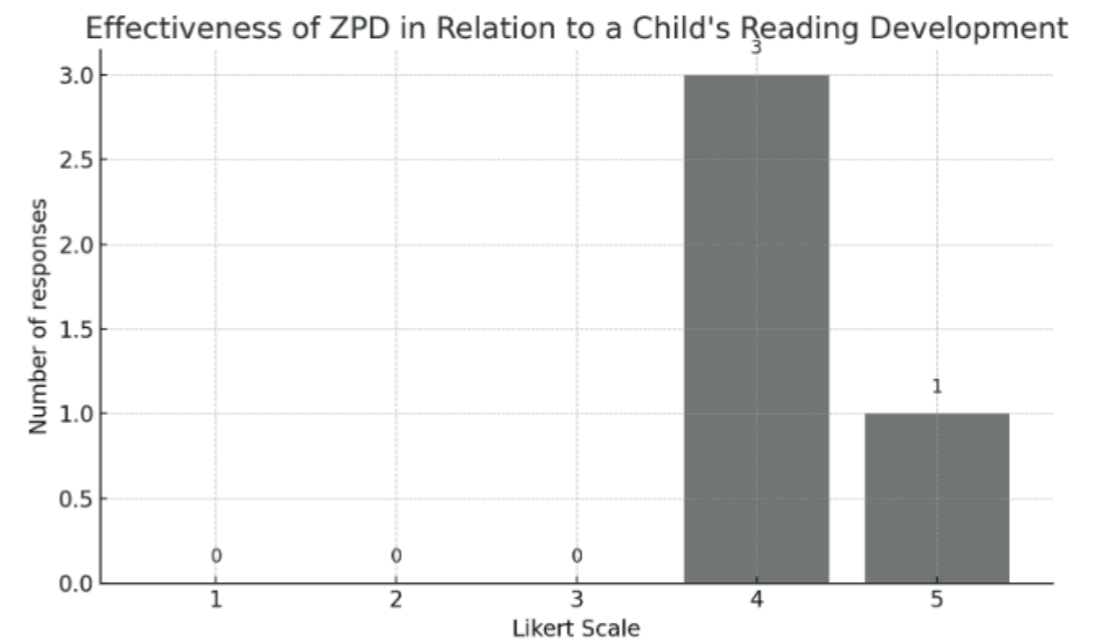


Figure 1 Participant answers to the question 'To what extent do you agree that ZPD is effective in relation to a child's reading development?'

It is illustrated in the graph that overall; all participants believe that ZPD is very effective in relation to supporting reading development in children. 75% of participants voted a 4 on the Likert scale and 25% of participants voted a 5 on the scale. In addition, the participants highlighted the importance of providing appropriate materials to provide encouragement, as well as illustrating how much children's reading development improves when guidance from an adult is provided. Participant 3 stated 'without support from an adult, the child won't know if they have read incorrectly, they need to know their strengths and improvements. Furthermore, Participant 4 commented 'it indicates how capable a child can be on their own but also how much they can excel when they have an adult working alongside them'. This suggests that all participants acknowledge the importance of ZPD in relation to reading development.

Similarly to the section above, two questions were combined in relation to scaffolding. It is apparent in the graph below (Figure 2) that all participants believe that scaffolding is an essential tool to support reading development in children.

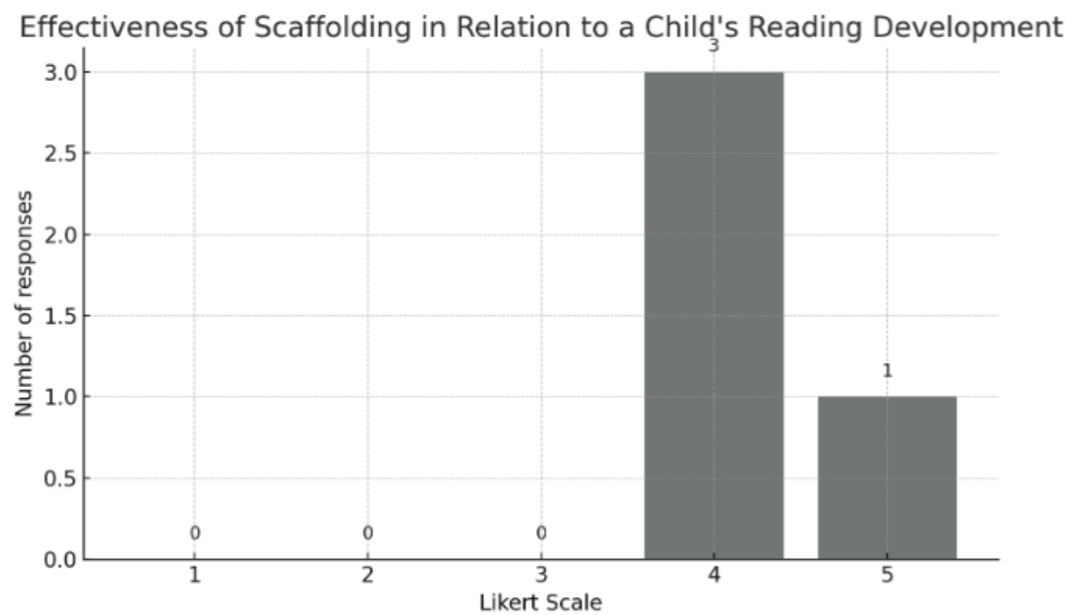


Figure 2 Participants answers to the question 'To what extent do you agree that scaffolding is effective in relation to a child's reading development?'

This graph is comparable to the graph above as 75% of participants voted a 4 on the Likert scale and 25% voted a 5. This suggests that all participants believe that scaffolding is essential to provide guidance to children. Furthermore, it was unanimous amongst the participants that scaffolding provides encouragement and that modelling behaviours is the most effective strategy to support development. Participant 1 reported that 'children require scaffolding in order to learn the basic skills of decoding and then comprehension, modelling and providing examples is key to this'. Additionally, Participant 3 stated that 'children need to be shown how to read and some tips and tricks which can support them. Children learn through copied behaviours and once a child can read, it will open many doors'. This indicates that the participants value scaffolding as an essential strategy to support reading development as they insist that modelling behaviours and providing guidance is of utmost importance.

### **Theme 2: More Knowledgeable Other**

It was illustrated within the responses gathered from the questionnaire that all participants believed that children could achieve more when working with an adult. Recurring phrases emerged from the data set including 'independent' and 'support'. Participant 1 stated 'what a child can do independently without help and what a child can do with guidance and support'. Participant 3 expressed the same opinion stating 'the ZPD is what a child can achieve with support from an adult'. This suggests that the participants have adequate knowledge on ZPD and how it applies to children's learning development.

The data collected in relation to scaffolding suggests that the participants have a sufficient understanding on scaffolding as phrases such as 'support' and 'more knowledgeable other' were evident in most of the responses. Participant 4 commented 'this is where the more knowledgeable other supports someone to achieve something'. Overall, by incorporating a

more knowledgeable other into supporting a child's reading development, it could be argued that providing support and guidance to children is influenced by Vygotsky's theories of ZPD and scaffolding.

## **DISCUSSION**

### **The influence of Vygotsky's theories on reading development.**

#### **Theme 1: Strategies to support reading development**

Research from Tajedini and Hashemzadeh and Sangari (2024) suggested that children are at risk of reading fatigue if reading development strategies are not implemented. Participant 3 commented 'support readers when I can sense their hesitation with words. Sometimes we take it in turns to read pages if the child is losing momentum.' Which supports Tajedini *Et al* (2024) hypothesis as Participant 3 implements reading strategies when they sense the child is experiencing reading fatigue.

The most obvious finding to emerge from the analysis is a MKO. Prior studies have noted the importance of an MKO as Mason & Signa) stated that an MKO provides scaffolding which supports children to achieve when reading. In reference to existent knowledge surrounding scaffolding, participant 4 commented 'this is where a more knowledgeable other supports someone to achieve something.' Which provides acknowledgement of the theory. Furthermore, without explicitly stating MKO, participants referred to providing guidance and support to children who are having difficulties reading.

Participant 3 stated they 'support readers when I can sense their hesitation with words. Sometimes we take it in turns to read pages if the child is losing momentum.' As mentioned by Vygotsky (1978, cited in Rose-Latson, 2021, pp. 33) children often learn better with materials best suited to their individual reading comprehension abilities. This was supported in the findings as Participant 1 reported that 'children are assessed and the reading books they read independently have a slight challenge.' Supporting Vygotsky's hypothesis of slightly challenging materials supports reading development in children.

Returning to the research question posed at the beginning of this study, it is now possible to state that Vygotsky's theories of ZPD and scaffolding influence reading development by providing a MKO to children who provide guidance and support to encourage independent reading. Additionally, by utilising ZPD inspired strategies such as Accelerated Reader children are able to access resources best suited to their individual needs which encourage them to reach their full potential. By employing ZPD and scaffolding into practice, it is evident in the literature review and the findings that children have more enjoyment reading with a MKO and are less likely to experience reading fatigue.

#### **Theme 2: Support to achieve**

The second question in this study sought out to determine how practitioners utilise ZPD and scaffolding in their practice. The results from this study indicate that all of the participants find ZPD and scaffolding effective in relation to reading development. Additionally, all participants use ZPD and scaffolding to promote reading development in their practice. The Likert scale gleaned that all participants voted higher than a 4, with 75% voting a 4 and 25%

voting a 5, insinuating that they believe that both ZPD and scaffolding are an effective tool in supporting reading development. (See figures 1 and 2) It was deduced that providing temporary support to children facilitated their reading comprehension abilities. It was inferred in the findings that guidance and support is a key component of supporting reading development in children which further supports Hong and Nguyen's (2019) hypothesis.

It can be concluded that practitioners value ZPD and scaffolding highly as they believe they are effective techniques to support reading development. Furthermore, it could be connoted that reading with a child is one of the most effective ways to promote reading as guidance and support is provided. Overall, it can be deduced that practitioners embed ZPD and scaffolding into their practice by reading with a child and providing guidance, as well as encouragement to read independently.

## CONCLUSION

The purpose of the current study was to determine how effective Vygotsky's theories of ZPD, and scaffolding are in relation to reading development in children, by using previous research. The findings clearly indicate that utilising a MKO as a reading strategy is an effective tool to promote reading development in children. Additionally, employing reading strategies such as Accelerated Reader has been proven by this study and previous research to provide fruitful reading development results. Furthermore, participants from this study unanimously agree that ZPD and scaffolding are beneficial strategies that they implement into their practice as they provide the children with guidance to eventually learn to read independently.

Although the study has successfully demonstrated the effectiveness of ZPD and scaffolding in relation to reading development, it had a certain limitation in terms of particular responses retrieved from the questionnaire. One participant, who has been a teaching assistant for 16 years commented on the questions asking for their understanding of ZPD and scaffolding, 'little'. The response of 'little' for both questions was a limitation within the analysis section as the one-word answer could not be effectively analysed in line with the research questions. There is, therefore, a definite need for further training within practice to enhance teaching assistant's knowledge of theories that they implement into their practice. Furthermore, as the participants have acknowledged, they are MKOs within their setting which could be argued that their knowledge should be further enhanced to ensure they are providing the most beneficial guidance to the children to support their reading development.

## Reference List

Ahmed, A. (2008) *Ontological, Epistemological and Methodological Assumptions: Qualitative Versus Quantitative* [Preprint].

Almalki, S. (2016) 'Integrating quantitative and qualitative data in mixed methods research—challenges and benefits', *Journal of Education and Learning*, 5(3), pp. 288–296.

Andrade C. (2018) 'Internal, External, and Ecological Validity in Research Design, Conduct, and Evaluation.', *Indian journal of psychological medicine*, 40(5), pp. 498–499.

Ash, D., & Levitt, K. (2003). Working within the zone of proximal development: Formative assessment as professional development. *Journal of Science Teacher Education*, 14(1), 23–48.

Barrett, D. & Twycross, A. (2018), 'Data collection in qualitative research', *Evidence - Based Nursing*, 21(3), pp. 63.

BERA (2024) *Ethical Guidelines for Educational Research*. 5th edn. Southwell: BERA.

Braun, V. and Clarke, V. (2006) 'Using thematic analysis in psychology', *Qualitative Research in Psychology*, 3(2), pp. 77–101.

Brundrett, M. and Rhodes, C. (2014) *Researching educational leadership and management methods and approaches*. London: Sage.

Faber, J., & Fonseca, L. M. (2014). How sample size influences research outcomes. *Dental press journal of orthodontics*, 19(4), 27–29.

Frega, R. (2018) 'The Social Ontology of Democracy', *Journal of Social Ontology*, 4(2), pp. 157–185.

Khaliliaqdam, S., (2014) 'ZPD, scaffolding and basic speech development in EFL context.', *Procedia-Social and Behavioral Sciences*, 98, pp.891-897.

Kivunja, C. and Kuyini, A.B. (2017) 'Understanding and applying research paradigms in educational contexts', *International Journal of Higher Education*, 6(5), p. 26.

Magno, C., (2010) 'The effect of scaffolding on children's reading speed, reading anxiety, and reading proficiency.', *TESOL Journal*, 3(2), pp.92-103.

Maguire, M. and Delahunt, B. (2017) 'Doing a Thematic Analysis: A Practical, Step-by-Step Guide for Learning and Teaching Scholars.', *Dundalk Institute of Technology*, 3.

Margolis, A.A., (2020) 'Zone of Proximal Development, Scaffolding and Teaching Practice.', *Cultural-Historical Psychology*, 16(3).

Mason, J.M. and Sinha, S. (1992). Emerging Literacy in the Early Childhood Years: Applying a Vygotskian Model of Learning and Development. Available at: <https://core.ac.uk/download/pdf/4826412.pdf>

Muzammil, L. and Saifullah (2021) 'Enhancing reading comprehension of junior high school students through scaffolding instruction', *Proceedings of the 2nd Annual Conference on Social Science and Humanities (ANCOSH 2020)* [Preprint]. doi:10.2991/assehr.k.210413.023.

Neumann, M.M., (2020) 'Teacher scaffolding of preschoolers' shared reading with a storybook app and a printed book.', *Journal of Research in Childhood Education*, 34(3), pp.367-384.

Obilor, E.I., (2023) 'Convenience and purposive sampling techniques: Are they the same.', *International Journal of Innovative Social & Science Education Research*, 11(1), pp.1-7.

Otoo, B. K. (2020) 'Declaring My Ontological and Epistemological Stance: A Reflective Paper.', *The Journal of Educational Thought (JET) / Revue de La Pensée Éducative*, 53(1), 67-88.

Palinkas, L.A. et al. (2013) 'Purposeful sampling for qualitative data collection and analysis in Mixed Method Implementation Research', *Administration and Policy in Mental Health and Mental Health Services Research*, 42(5), pp.

Renaissance. (2024a) *Accelerated Reader: Motivating Independent Reading*. Available at: <https://www.renaissance.com/products/accelerated-reader/> (Accessed: 04/04/24)

Renaissance. (2024b) *Zone of Proximal Development*. Available at: <https://arhelp.renaissance.com/hc/en-us/articles/12746104128027-Zone-of-Proximal-Development> (Accessed: 04/04/24)

Rogoff, B., Malkin, C., & Gilbride, K. (1984) 'Interaction with babies as guidance development.', *New Directions for Child and Adolescent Development*, 23, pp. 31-44.

Rose Latson, R.L., (2022). Effects of Scaffolding on Reading Comprehension.

Stratton, S.J., (2021) 'Population research: convenience sampling strategies.', *Prehospital and disaster Medicine*, 36(4), pp.373-374

Tajedini, O., Hashemzadeh, M.J. and Sangari, M., (2024) 'Content Analysis of Articles on Reading Culture and Habits: A Case of LIS Journals Indexed in Science Direct And ISC.', *International Journal of Information Science and Management (IJISM)*, 22(1), pp.261-275.

Tenny S, Brannan JM, Brannan GD. (2022) *Qualitative Study*. Available at: <https://www.ncbi.nlm.nih.gov/books/NBK470395/#:~:text=Qualitative%20research%20at%20its%20core,One%20of%20the%20strengths%20of> (Accessed: 14/04/24)

Wiltshire, G. and Ronkainen, N., (2021) 'A realist approach to thematic analysis: making sense of qualitative data through experiential, inferential and dispositional themes.', *Journal of Critical Realism*, 20(2), pp.159-180.



# Injectable Treatments for Skin Aging: A Comparison of BoNT-A and Polynucleotide Treatments

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## ABSTRACT

*This paper discusses botulinum toxin type A (BoNT-A) and polynucleotides (PN). Exploring and comparing the two popular injectable treatments, specifically in their effectiveness at addressing the visible signs of aging on the skin of the face. The author uses recent clinical studies and scientific literature to outline the process in which they work, the treatment outcomes and safety considerations for both treatments. BoNT-A offers a near instant result for dynamic wrinkle reduction; however, it may limit expressiveness of the face and does not offer any regenerative benefits. In opposition, PN require multiple treatments over an extended period to achieve visible results, which include an improvement in overall skin health, elasticity and texture. The author concludes that PN treatments present a promising alternative to, or a treatment to compliment BoNT-A, particularly for those patients looking to improve skin quality and subtle aesthetic enhancement.*

**KEY WORDS:** Aesthetic Medicine, Botulinum Toxin A, Polynucleotides, Skin Aging, Injectable Treatments

## INTRODUCTION

In 2023, the British Beauty Council (2024) reported that the Beauty and Personal Care Industry contributed £27.2 billion to the UK gross domestic profit. In relation to injectable aesthetic treatments specifically, Geddes (2023) reports that the market is predicted to increase a further 15.4% by 2030. These minimally invasive injectable treatments are continuing to grow in popularity to combat the visible signs of aging on the skin (Shin, Lee, Rho, and Park, 2023).

Skin aging is an inevitable process that is affected by both intrinsic and extrinsic factors. Ghatge and Ghatge (2023) discuss in their paper that the main contributing factors to ageing skin is the breakdown and changes within the acellular dermal matrix (ADM) which is composed of the extracellular matrix (ECM) and the dermal layer of the epidermis. Specifically, within the ECM, both intrinsic and extrinsic factors cause degradation of the proteins, collagen and elastin, which are responsible for the structural integrity of the dermis. According to Tsatsou et al. (2012), the visible signs linked with aging skin are rhytides, wrinkles, more apparent areas of pigmentation, telangiectasia and an increase coarseness to the texture of the skin. These changes occur as a natural result of intrinsic, genetic, aging.

However, the speed of their onset is influenced significantly by extrinsic or environmental factors. They list the two main causes of this as being UV exposure and smoking.

This report will compare two different medical-aesthetic treatments, injectable anti-wrinkle and polynucleotide treatments. It will discuss the concept and usage of each treatment, and their effectiveness in relation to treating the perceived signs of aging on the skin, caused by both intrinsic and extrinsic factors.

## POLYNUCLEOTIDE TREATMENTS

Dermal fibroblasts are responsible for the production of the structural elements of the ECM. The structural proteins that make up the ECM comprise collagen, elastin, fibronectin, laminin and tenascin (Kular, Basu, and Sharma, 2014). According to Fisher, Varani, and Voorhees (2008) fibroblasts in aged skin produce high levels of collagenases, and low levels of collagen. The aging process is accelerated when these processes become out of balance.

As well as the collapse of the fibroblast function, they also decrease in number, with a reported reduction of 35% in aged skin (80 years) in comparison to young skin, 18-29 years (Varani, et al 2000).

In recent years the benefits of using polynucleotides (PN) as injectable biostimulators to boost fibroblast activity in medical aesthetic treatments has become more popular because of their ability to stimulate rejuvenation of the skin at a cellular level. They were first used as a facial aesthetic skin booster treatment in 2014, under the brand name Rejuran (Yi et al, 2024).

PN are made up of chains of nucleotides, linked by covalent bonds, which form the basic structure of deoxyribonucleic acid (DNA) and ribonucleic acid (RNA). PN play a vital role in cell proliferation during the wound healing process and overall epidermal cell turnover, and support cell differentiation. They are categorised under the subtype of aesthetics known as regenerative medicine. Dr. Khan (2021) suggests that reversing the aging of dermal and epidermal tissues, improving overall skin health and visibly repairing scar tissues are all being achieved with regenerative medicine, such as PN.

PN are extracted from the gonads of chum salmon or trout and are increasing in popularity, in part due to their biocompatibility with the human body. They are purified and incorporated into a gel that can be injected into the area of the skin to be treated (Lee *et al.*, 2024). The gel commonly includes a hyaluronic acid (HA) to further boost the results of the treatment. A review conducted by Lee *et al.* (2024) reports that PN have been shown to demonstrate significant improvements in both hydration and skin elasticity, as well as improving overall facial appearance, including skin texture and wrinkles.

Khan *et al.* (2022) report that when injected into the dermis, PN inhibit the production of matrix metalloproteinases (MMPs), which are responsible for the degradation of the ECM. They also state that PN stimulate the binding of adenosine, to the A2A receptors in the dermis which increases protein synthesis in the cells of the dermis. The PN therefore stimulates the

dermal fibroblasts, activating the adenosine receptors, increasing collagen synthesis and reducing the production of MMPs. (Marucci *et al.*, 2022).

PN treatments are indicated for those clients who wish to achieve tissue regeneration along with a healthier appearance to the skin, due to their ability to improve the skin quality in all areas that are treated (Cavalleni *et al.*, 2020). Park *et al.* (2015) reported that following a course of PN treatments, patients in their forties demonstrated improvements in pigmentation, evenness of skin tone, wrinkles and sagging. Lee *et al.* (2023) also report promising findings for using PN for treating facial erythema caused by inflammatory dermatosis, with 88.1% of those treated reporting that PN were “highly effective”. According to Kremerov (2022), published in the Journal of Aesthetic Medicine, three treatments spaced three to four weeks apart are recommended for optimal results.

A study conducted by Lee *et al.* (2023) reported that 96.6% of those treated with PN during the trial reported no adverse reactions, and any reactions that were reported were due mainly to localised epidermal trauma at the injection site, including redness, swelling and mild bruising. Lee *et al.* (2024) concludes that in the studies evaluated there were no major adverse effects to the use of PN for facial rejuvenation. Interestingly, Lee *et al.* (2024) also reports that although research has suggested and proved many benefits of PN, more research is needed for them to be fully understood on a cellular level and for them to be used to achieve the best possible outcome for patients.

## ANTI-WRINKLE TREATMENTS

BMJ (2022) reports that wrinkles appear as a natural byproduct of the aging process. The creases and lines on the skin are often most apparent over areas of the body which have had prolonged ultra-violet (UV) exposure. Repeated facial muscle contraction results in dynamic wrinkles caused by movement of the face during expression and speech (Swift *et al.*, 2020). Dynamic wrinkles become static as time passes due to the decrease in collagen and elastin within the dermis, and as MMPs increase in quantity.

The decrease in dermal fibroblast number and activity has a direct impact on the quantity and quality of collagen within the dermis. Collagen is the main structural protein within the skin (Shin *et al.*, 2019). Torebjörk, Fisher, Kim and Quan (2023) report that the clinical signs of aging on the skin, such as increased fragility and static lines and wrinkles is caused mainly by the alteration of collagen during the aging process. These changes are further amplified by UV exposure due to the formation of reactive oxygen species (ROS). ROS damage the ECM due to the degradation of the collagen fibres (Nakai and Tsuruta, 2021).

According to Swift *et al.* (2020), the upper third of the face shows signs of ageing through visible wrinkles on the forehead and glabellar. The horizontal lines appearing in this area are a result of dynamic movement of the frontalis muscle, and any vertical lines are what Swift (2020, p.1112) describes as “sleep-crunch” lines. The lines that appear in the periorbital region, commonly known as crow’s feet, are a result of the dynamic movement of the orbicularis oculi muscle, usually during smiling.

There are seven types of botulinum toxin available, named A-G, however only A and B are typically used in clinical settings. Botulinum toxin serotype A (BoNT-A) is most used for cosmetic purposes (Satriyasa, 2019). BoNT-A has been used for aesthetic purposes since 1987 (Ashenburg and Canada, 2018). BoNT-A is produced by the toxin *Clostridium botulinum* (Satriyasa, 2019) and it is often referred to as Botox, however this is a brand name, and is one of many brands of injectable anti-wrinkle treatment available.

When BoNT-A is injected into a muscle, it binds to the nerve endings and prevents the acetylcholine from being released, causing temporary paralysis, or relaxation (Witmanowski and Błochowiak, 2020). Acetylcholine is a neurotransmitter released by neurons for the purposes of communication (Sam and Bordoni, 2023).

The frontalis muscle is responsible for raising the eyebrows, and when treated with BoNT-A successfully, it can stop the horizontal wrinkles across the forehead. When the corrugator and procerus muscles are treated successfully, it stops the vertical lines forming between the eyebrows, over the glabellar (Satriyasa, 2019). More advanced treatments can also be performed including injecting the orbicularis oculi, which is responsible for pulling the brow downwards, in the outer third of the brow to achieve a slight brow lift. When the treatment is used to prevent dynamic lines, it can prevent static lines from forming and even reduce their appearance if the relevant muscles are relaxed for an extended period (Bryant, 2022).

Although BoNT-A is usually used to treat the muscles of expression in the face, it can be used in many regions of the face to counteract the signs of aging on the skin through muscle relaxation. Examples of these include facial contouring by treating the masseter muscle; bunny lines can be prevented by treating the nasalis muscle. Suber, Dinh, Prince, and Smith (2014) also report that a gummy smile can be improved by treating the levator labii superioris alaeque nasi and levator labii superioris muscles.

Although adverse reactions from treatment using BoNT-A are not common, they can still occur. Due to the anatomy of the facial muscles, in rare occasions the client may suffer with unilateral eyelid ptosis after treatment in the corrugator with BoNT-A (Satriyasa, 2019). This can be caused by poor anatomical knowledge, or through product migration through the orbital septum into the eyelid levator muscle. This is said to occur in 1-5% of treatments (Yiannakopoulou, 2015). Other adverse effects may include asymmetry from a brow lift, a heaviness in the glabellar region after treatment of the frontalis, reduced muscle relaxation or no result from treatment at all.

A study completed by Ho *et al.* (2022) discusses the increase in clients reporting a resistance to BoTN-A treatments. These are reported as either a reduction in the time the results last, or that the treatment is limited to no result. This happens due to the formation of neutralising antibodies (NAb) which inhibit the BoTN-A from binding to the nerve endings of the neurotransmitters.

## COMPARISON

BoNT-A for wrinkle relaxing treatments and PN have both been successful in limiting the visible signs of aging on the skin. BoNT-A is the most popular treatment in this field, with over 900,000 treatments carried out in the UK in 2022 (Bryant, 2022). PN treatments in comparison are a relatively new treatment, and there are not yet any studies which have collated reliable data regarding their volume of use. There are however a growing number of studies reporting on the effectiveness of PN to allow comparison to BoNT-A treatments, including those cited previously by Cavalleni *et al.* (2020), Yi *et al.* (2024) and Lee *et al.* (2024).

Overall skin health can play a significant part in the outcome of aesthetic treatments for anti-aging. Krememrov (2022) recognises that poor skin quality can limit the effectiveness of anti-wrinkle treatments, leaving the results lacking in the attempt of facial rejuvenation. Treatments with PN improve the overall health of the skin through the stimulation of dermal fibroblasts, as well as the introduction of a boost of hyaluronic acid into the dermis (Cavalleni, 2020). As BoNT-A is a neurotoxin it plays no part in improving skin health, offering limited results for clients with significant laxity in the skin.

BoTN-A treats dynamic wrinkles through relaxation of the muscle, although it may minimise the appearance, it is not always successful in treating static lines, particularly in the glabellar region. PN can achieve a noticeable result on static lines due to its bio-stimulation properties.

The reduced ability to express facial emotions when treated with BoTN-A may negatively impact those who rely on facial expression, for example actors, those communicating with children or other public speakers. Witmanowski and Błochowiak, (2020) report in their study that these changes in expression can sometimes even become permanent after repeated treatments with BoTN-A. There is no such change in dynamic movement of the facial muscles with PN treatments, allowing those treated to express a full range of emotion and expression with their faces.

The effects of BoTN-A treatments happen rapidly after the initial appointment. There is only one appointment needed to achieve noticeable results, except for a possible review appointment when a small amount of additional BoTN-A may be administered to either correct or enhance results. Within two weeks of the initial treatment the full results are visible (Satriyasa, 2019). For maximum results to be achieved with PN, three treatments are required, spaced at three-to-four-week intervals. The full results of the treatment then take up to twelve weeks from the last treatment to be visible on the skin (Krememrov, 2022). This is due to the bio-stimulation nature of the treatment and the time taken for the collagen and elastin to generate to a noticeable degree.

## CONCLUSION

The availability of BoTN-A and PN treatments and the minimal epidermal trauma associated with them, other than a slight risk of bruising at the injection site, make them both appealing options (Shin, Lee, Rho, and Park, 2023).

Anti-wrinkle treatments using BoTN-A offer an immediate and noticeable result on the face of those treated. Dynamic movement lines are reduced, if not eliminated, and the outcomes of the treatment are predictable and reliable, when it is administered by a well trained and experienced practitioner, as suggested by Alotaibi, Alsukait, Alsalman and Turkmani (2022). This can however lead to an unnatural or mask-like look to the face (Baumeister, Papa and Foroni, 2016).

PN treatment results are more subtle. Rather than stopping movement of the face, the skin is stimulated to rejuvenate itself from within, making it an exciting option for those client's wanting an overall improvement in their skin health. Improving the firmness, reducing pigmentation and improving visible radiance of the skin has been shown in a study by Lim (2024) to improve self-esteem and attractiveness regardless of gender. Although the effects of the treatment take longer to become visible, to achieve improved skin health, hydration and a more youthful appearance, PN are shown to be the best option for treatment in the first instance, to achieve a more naturally enhanced appearance.

## REFERENCE LIST

Ashenburg, K. (2018) The Real History Behind the Birth of Botox. Available at: <https://www.readersdigest.ca/health/beauty/birth-botox/> (Accessed 20 October 2024).

Baumeister, J.C., Papa, G. and Foroni, F. (2016). 'Deeper than skin deep – The effect of botulinum toxin-A on emotion processing', *Toxicon*, 118, pp.86–90.

BMJ (2024) *Wrinkles – Symptoms, diagnosis and treatment*. Available at: <https://bestpractice.bmj.com/topics/en-gb/859>. (Accessed: 13 October 2024).

British Beauty Council (2024) *The value of beauty, British Beauty Council*. Available at: <https://britishbeautycouncil.com/mp-files/the-value-of-beauty.pdf/> (Accessed: 07 October 2024).

Bryant, M. (2022). 'They've lost the plot': leading cosmetic doctor says under-30s are overdoing Botox and fillers. The Guardian. Available at: <https://www.theguardian.com/lifeandstyle/2022/dec/18/cosmetic-surgeon-botox-fillers-instagram-generation-safety-concerns>. (Accessed 13 October 2024).

Cavallini, M., Bartoletti, E., Maioli, L., Massirone, A., Pia Palmieri, I., Papagni, M., Priori, M. and Trocchi, G. (2020). Consensus report on the use of PN-HPT™ (polynucleotides

highly purified technology) in aesthetic medicine. *Journal of Cosmetic Dermatology*, 20(3), pp.922–928.

Fisher, G.J., Varani, J. and Voorhees, J.J. (2008) 'Looking older', *Archives of Dermatology*, 144(5).

Geddes, L. (2023). *More and more people are having 'tweakments'. But what do we really know about the long-term effects?* The Guardian. Available at: <https://www.theguardian.com/lifeandstyle/2023/oct/02/tweakments-market-booming-what-do-we-know-about-long-term-effects> (Accessed 2 Oct. 2023).

Ghatge, A.S. and Ghatge, S.B. (2023) 'The effectiveness of injectable hyaluronic acid in the improvement of the Facial Skin Quality: A systematic review', *Clinical, Cosmetic and Investigational Dermatology*, Volume 16, pp. 891–899.

Ho, W.W.S., Albrecht, P., Calderon, P.E., Corduff, N., Loh, D., Martin, M.U., Park, J.-Y., Suseno, L.S., Tseng, F.-W., Vachiramon, V., Wanitphakdeedecha, R., Won, C.-H., Yu, J.N.T. and Dingley, M. (2022). *Emerging Trends in Botulinum Neurotoxin A Resistance: An International Multidisciplinary Review and Consensus*. *Plastic and Reconstructive Surgery. Global Open*, 10(6), p.4407.

Khan, A. (2022) *Regenerative medicine in aesthetic treatments: Stem Cells, stromal vascular fraction, platelet rich plasma, and platelet rich fibrin*. Boca Raton, FL: CRC Press. Quoted in: Kremerov, A. (2022) *Introducing Polynucleotides, Journal of Aesthetic Nursing*. Available at: <https://www.aestheticnursing.co.uk/content/comment/introducing-polynucleotides/> (Accessed: 09 October 2024).

Khan, A., Wang, G., Zhou, F., Gong., L., Zhang, J., Qi, L. and Cui, H. (2022) 'Polydeoxyribonucleotide: A promising skin anti-aging agent', *Chinese Journal of Plastic and Reconstructive Surgery*, 4(4), pp. 187–193.

Kular, J.K., Basu, S. and Sharma, R.I. (2014) 'The extracellular matrix: Structure, composition, age-related differences, tools for analysis and applications for tissue engineering', *Journal of Tissue Engineering*, 5.

Kremerov, A. (2022) *Introducing Polynucleotides, Journal of Aesthetic Nursing*. Available at: <https://www.aestheticnursing.co.uk/content/comment/introducing-polynucleotides/> (Accessed: 09 October 2024).

Lee, D., Kim, M.J., Park, H.J., Rah, G.C., Choi, H., Anh, S., Ji, G.H., Kim, M.S., Kim, G., Shin, D.W. and Oh, S.M. (2023) 'Current practices and perceived effectiveness of polynucleotides for treatment of facial erythema by cosmetic physicians', *Skin Research and Technology*, 29(9).

- Lee, K.W., Chan, K.W.L., Lee, A., Lee, C.H., Wan, J., Wong, S. and Yi, K. (2024) 'Polynucleotides in Aesthetic Medicine: A review of current practices and perceived effectiveness', *International Journal of Molecular Sciences*, 25(15), p. 8224.
- Lim, T. S. (2024) 'Polynucleotides HPT for Asian Skin Regeneration and Rejuvenation', *Clinical, Cosmetic and Investigational Dermatology*, 17, pp. 417–431.
- Marucci, G., Buccioni, M., Varlaro, V., Volpini, R. and Amenta, F. (2022) 'The possible role of the nucleoside adenosine in Countering skin aging: A review', *BioFactors*, 48(5), pp. 1027–1035.
- Nakai, K. and Tsuruta, D. (2021). What Are Reactive Oxygen Species, Free Radicals, and Oxidative Stress in Skin Diseases? *International Journal of Molecular Sciences*, 22(19), p.10799.
- Park, K.Y., Seok, J., Rho, N.K., Kim, B.J. and Kim, M.N. (2015) 'Long-chain polynucleotide filler for skin rejuvenation: Efficacy and complications in five patients', *Dermatologic Therapy*, 29(1), pp. 37–40.
- Sam, C. and Bordoni, B. (2023). *Physiology, Acetylcholine*. PubMed. Available at: <https://www.ncbi.nlm.nih.gov/books/NBK557825/>. (Accessed 20 October 2024).
- Satriyasa, B.K. (2019) 'Botulinum toxin (Botox) A for reducing the appearance of facial wrinkles: A literature review of clinical use and pharmacological aspect', *Clinical, Cosmetic and Investigational Dermatology*, Volume 12, pp. 223–228.
- Shin, J.W., Kwon, S.H., Choi, J.Y., Na, J.I., Huh, C.H., Choi, H.R. and Park, K.C., 2019. Molecular mechanisms of dermal aging and antiaging approaches. *International journal of molecular sciences*, 20(9), p.2126.
- Shin, S.H., Lee, Y. H., Rho, N and Park K. Y. (2023) 'Skin aging from mechanisms to interventions: Focusing on dermal aging', *Frontiers in Physiology*, 14.
- Suber, J.S., Dinh, T.P., Prince, M.D. and Smith, P.D. (2014). Botulinumtoxin A for the Treatment of a 'Gummy Smile'. *Aesthetic Surgery Journal*, 34(3), pp.432–437.
- Swift, A., Liew, S., Weinkle, S., Garcia, J.K. and Silberberg, M.B. (2020). The Facial Aging Process From the 'Inside Out'. *Aesthetic Surgery Journal*, [online] 41(10).
- Tsatsou, F., Trakatelli, M., Patsatsi, A., Kalokasidis, K., and Sotiriadis, D. (2012) 'Extrinsic aging', *Dermato-Endocrinology*, 4(3), pp. 285–297.

- Torebjörk, H.E., Fisher, G.J., Kim, A. and Quan, T. (2023). Age-related changes in dermal collagen physical properties in human skin. *PLOS ONE*, 18(12), pp.e0292791–e0292791.
- Varani, J., Warner, R. L., Gharraee-Kermani, M., Phan, S. H., Kang, S., Chung, J. H., Wang, Z. Q., Datta, S. C., Fisher, G. J., & Voorhees, J. J. (2000). Vitamin A antagonizes decreased cell growth and elevated collagen-degrading matrix metalloproteinases and stimulates collagen accumulation in naturally aged human skin. *The Journal of Investigative Dermatology*, 114, 480–486.
- Witmanowski, H. and Błochowiak, K. (2020). The whole truth about botulinum toxin – a review. *Advances in Dermatology and Allergology/Postępy Dermatologii i Alergologii*, [online] 37(6), pp.853–861.
- Yi, K., Winayanuwattikun, W., Kim, S., Wan, J., Vachatimanont, V., Putri, A. I., Hidajat, I. J., Yogya, Y. and Pamela, R. (2024) 'Skin boosters: Definitions and varied classifications', *Skin Research and Technology*, 30(3).
- Yiannakopoulou, E. (2015). Serious and Long-Term Adverse Events Associated with the Therapeutic and Cosmetic Use of Botulinum Toxin. *Pharmacology*, [online] 95(1-2), pp.65–69.



# Cultivated Meat: An Introduction to its Challenges, Solutions and Benefits

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## ABSTRACT

*Cultivated meat is a new and emerging technology borne from the intersection of cellular science and bio-nutrition, with the aim of producing animal tissues for consumption. This technology stands to improve public health, the climate impact of agriculture, and animal welfare, whilst also having the potential to overtake conventionally farmed meat in economic accessibility. At present, food regulations are yet to fully integrate cultivated meat, and the uncertainty surrounding legality is generating scepticism and triggering political opposition in some regions. However, some nations such as the United States of America, Israel, and the Republic of Korea are eager to capitalise on its potential, investing in the technology's development, and researching the projected benefits. There are moral and economic concerns surrounding the source of certain materials used in the process, however these are expected to be replaced with more ethical and affordable alternatives as they are developed.*

**KEYWORDS:** cell culture, cultivated meat, dietary health, ethical eating, sustainable food production.

## INTRODUCTION

Cultivated meat (CM), also known as clean, cultured or lab-grown meat, is the product of the in-vitro (outside of an animal) culturing of animal cells with the purpose of partially or completely replacing traditionally acquired animal flesh for human and pet consumption. The technology has garnered interest in recent years for its potential environmental, ethical, economic, and health benefits when compared to the consumption of flesh from livestock (Kirsch *et al.*, 2023; Santos *et al.*, 2024; Singh *et al.*, 2024). The reduced land area required to manufacture the material offers a major avenue for cost cutting in the animal agriculture industry (Filippin *et al.*, 2023), but while the technology has advanced rapidly, it still stands to benefit from further streamlining before quality and cost can reach commercial standards and compete with conventional farming (Lee *et al.*, 2022).

CM is produced by extracting relevant stem cells from animal tissues, providing them with nutrient-rich media and a scaffold against which to bind and differentiate in-vitro, and harvesting the grown meat for consumption (Riess *et al.*, 2021).

In this report, recent progressions in CM research are discussed, as well as their implications to the fields of health, ethics, economics, and environmentalism. The challenges facing the new and emerging science are reviewed, as well as their potential solutions and the long-term benefits of full implementation.

## CHALLENGES

Although the technology shows promise, there are many barriers to its adoption, namely the economic difficulties associated with CM, which prevent wide-spread commercial use. Production improvements are required to create a more viable cost-to-yield ratio for wide-spread use (Thyden *et al.*, 2022), although some companies are entering the marketplace successfully already (Douglas, 2023).

Most of the costs associated with production of CM arise from the extraction of media, which accounts for more than 99% of the expenses. This is largely due to the medium ingredients being pharmaceutical grade, rather than food grade, which would potentially be cheaper. Foetal bovine serum (FBS) currently makes up the greatest share of medium, as it is rich in hormones, growth factors, cell attachment factors, and various nutrients. Synthetically reproducing an alternative to this naturally occurring media source has historically proved difficult in various fields of cell culture research, and as of 2023, only one producer worldwide had achieved it for CM applications (Santos *et al.*, 2024; Mark *et al.*, 2013; Vegconomist, 2023).

Another technical constraint facing the CM industry is finding an effective way to recreate the ratio of different types of animal tissue in a single food item. The heterogenous nature of organs is essential for the function that they perform, but it also contributes significantly to the texture and flavour of the material. There have been various attempts to overcome this however, and some approaches have seen success (Pallaoro *et al.*, 2023).

CM is also facing legal assessment, with varying levels of acceptance being found internationally. Singapore, the United States, the People's Republic of China, Israel, and the Republic of Korea have publicly announced to financially support, or continue supporting, the development of CM for public consumption (Lewisch & Riefler, 2023). On the contrary, the Italian government has showed resistance to this advancement, drafting a plan to ban CM in March 2023. However, mass signees of a petition to block the regulation led to the withdrawal of the Technical Regulation Information System notification submitted to the EU in October (Lorenzo, 2023).

As well as regulatory scrutiny, public perception also raises a challenge, even in countries where CM is gaining legal status and government endorsement. The public have a certain amount of food neophobia that needs to be overcome before it gains perception as a safe and viable alternative to conventional meat by the majority of the population. A pro-CM social factor, however, is food curiosity, which generates attention quickly once a new food product enters the market. New foods often trigger mass eagerness to sample them to build an opinion for social discourse, which may lead to greater uptake long-term (Hwang *et al.*, 2020).

## SOLUTIONS

Various platforms exist to culture mammalian cells for drug development purposes. However, unlike the Chinese hamster ovary cells used in drug development (Haldankar, 2006), the cells being used to cultivate meat must bind to a scaffold in order to grow, so new alternatives to current bioreactor technologies must be developed (Wee *et al.*, 2023).

In the search for practical scaffolds that facilitate cellular differentiation and tissue formation, various materials have been explored, with an emphasis on the accessibility of the scaffold,

and their nutrition and flavour profiles. Materials such as textured soy proteins (Wee *et al.*, 2023), decellularised button mushroom tissue (Singh *et al.*, 2024) and decellularised broccoli florets have been investigated, but the optimal choice is yet to be identified.

As well as scaffolds, media is required to fulfil the nutritional requirements of the meat being produced. FBS is currently used for culturing bovine meats; however, alternatives are being studied to cut costs and reduce the variation between batches. Human platelet lysate serum is an ongoing area of study for cell culture, offering an alternative to FBS. The medium is obtained through freeze-thaw cycles, releasing growth factors et cetera from the platelets. This alternative would also reduce ethical concerns as the material is acquired with consent, and without destroying the subjects (Duarte Rojas *et al.*, 2024). However, any serum-based media inherently possesses the drawbacks of greater inter-batch variation and lower purity, limitations that chemically defined mediums (CDMs) overcome. CDMs have the advantage of high consistency in their composition, therefore generating more repeatable results, while abstaining from causing animal suffering (Cattaneo *et al.*, 2024).

An avenue for efficient meat culture is found in the high scalability of bioreactors, with facilities being able to expand to fit demand as public investment in cultivated meat products increases. Industry will also gain an improved ability to match the fluctuations in global population compared with conventional farming (Harsini & Swartz, 2023). Perfusion models utilising packed bed, fluidised bed, or hollow fibres for cell adherence greatly reduce the volume of media required per Kg of meat produced, reducing costs and warehousing constraints, although this technology's development is still behind simpler culture plates in some areas (Sugii *et al.*, 2023).

## BENEFITS

Beyond the naturally occurring components of meat that are harmful to human health (Jung *et al.*, 2022), various toxins also bioaccumulate in animal tissues, such as the mercury found in fish (Lepak *et al.*, 2023). Aside from the negative health effects caused by consuming animal-based foods long-term, there are also shorter-term, sudden, and widespread health risks in the form of zoonotic disease. Various epidemics and pandemics are associated with animal-based foods such as Cov-Id19, Human immunodeficiency viruses, and swine flu, with the continued consumption of animal-products increases the risk of this reoccurring (Yang *et al.*, 2023). As CM is not obtained from external sources that are exposed to toxins in the environment or pathogens, these risks are mitigated (Niemiec *et al.*, 2021; Singh *et al.*, 2024; Gaydhane *et al.*, 2018). CM additionally removes the reliance on antibiotics used in conventional farming in many countries, as well as the requirement for hormone addition, mitigating associated public health risks specific to meat consumption (Hwang *et al.*, 2020). Due to how wide-spread meat consumption is, and how much its consumption scales-up with population increase (Kirsch *et al.*, 2023), the negative health impacts of meat consumption could be reduced substantially by switching to CM.

CM also offers a major response to growing concerns surrounding the difficulties of overpopulation in certain regions, the growth of population in response to food availability (Hopfenberg & Pimentel, 2001) and the environmental damage dealt when humans attempt to gain food security (Chowdhury *et al.*, 2022). With the global human population continuing to

rise (Gu et al, 2021), CM could provide a much-needed reduction to the food supply pressure and allow time for a more permanent solution. 77% of the Earth's farmed surface is used for rearing livestock, while 23% is for crops for human consumption, however the land utilised for the former generates only 18% of the calorific intake of humans. In shifting the meat industry to CM, millions of km<sup>2</sup> of farmland could be freed up for housing, facilities, and rewilding, alleviating the pressure of population growth, and benefiting biodiversity (Selwyn *et al.*, 2025). Furthermore, with meat being the most environmentally impactful animal-based food, increasing the efficiency by which it is produced will have a significant impact on a wide variety of pollution sources (Warner, 2023; Filippin *et al.*, 2023).

### ETHICAL ISSUES

Until a sufficiently effective chemically defined medium can be developed, FBS will likely remain a primary medium source used in CM production, despite inter-batch variation and the ethical concerns that reduce the favourability of its use (Duarte Rojas *et al.*, 2024; Santos *et al.*, 2024; Warner, 2019). FBS is harvested via the un-anaesthetised extraction of calves from pregnant cows, shortly before a cardiac puncture provides the means to remove the blood from the young. This process is believed to be painful, reducing the life of calves to C-section, and immediate death. This practice is viewed as unethical by scientists studying cell culture (Jochems *et al.*, 2002; Evan *et al.*, 2006) and animal rights groups (Vegonomist, 2023; Animal-Free Science Advocacy, 2013), who both call for the end to this violent practice and the development of alternatives.

Reports of food neophobia indicate public anxiety surrounding the change to the food-supply status quo that widespread uptake of CM would bring. This indicates resistance to consumer engagement with the new technology (Hwang *et al.*, 2020).

In opposition to which is the food curiosity generated, with 40-80% of first impressions recorded as being a 'wow' response. Public opinion partially lingers on feelings of 'unnaturalness' surrounding CM, with it being said that man-made meat disconnects us from nature (Hwang *et al.*, 2020; Decc, 2020). Subversively, there is evidence to suggest that humans evolved as prey animals (Hart & Sussman, 2018), and that since our digestive systems reflect the physiology of herbivores, it can be argued that our consumption of animal products at all is unnatural (Lambert, 2011). Human technological exploitation for farming illustrates the pre-existing unnaturalness surrounding meat consumption, especially when considering the large populations of animals that must be maintained to supply current demand. (Decc, 2020). Evolutionarily, it is observed that predation culminates in complex behavioural interactions, with predators being anatomically equipped for hunting (Moya *et al.*, 2022), adaptations that are absent in humans.

Despite the public's generally positive reception to more ethical products, there remains a disparity between what people believe is right and what they will actively support. This is caused partially by perceived economic difficulties associated with moral living, leading to stagnation in progressive behaviours when alternatives are present (Yang, 2023). A further psychological barrier is linked to the subconscious compartmentalisation of incongruent moral beliefs and behaviours which are taken for granted as normality, a process which

creates phantasms. Phantasms allow for conflicting moral beliefs to be held simultaneously, and function as a coping mechanism for what would otherwise be distressing to consider. A relevant example being the belief that hurting animals is wrong, while funding their farming (Tenev, 2022).

### CONCLUSIONS AND RECCOMENDATIONS

In conclusion, the new and emerging science of cultivated meat has seen rapid advances in the last decade and looks to continue its development as an increasing number of countries and corporations back its study.

Attempts to streamline production has revealed many unique difficulties facing the infant industry, such as medium selection; where it is sourced, how much is needed, and what composition should be targeted when developing chemically defined media. Scaffold design is a large area of study in the field as the optimal framework for livestock cell adherence is yet to be found. The models vary in their origins, with research groups investigating the use of textured soy proteins, broccoli florets, and button mushroom tissues, among others. As for equipment selection, various systems are being investigated, some already seeing use in cultured meat production on a small scale, while others are adapted versions of existing technology from other industrial uses of cell culture.

Once processes have been well characterised, cultured meat will increase the efficiency of manufacturing, in turn substantially reducing the resources required to generate the material. This will bring down costs, making products more accessible to consumers, solidifying CM's potential to become the future means by which humans produce meat.

Beyond the accessibility improvements, cultured meats could also provide personal health benefits, removing the risk of trans-species pathogens causing epidemics and pandemics as they have regularly done in the past.

Of major interest, given the current climate of environmentalist movements, is the reduction of carbon emissions that could come of the mass-uptake of cultivated meat by the public. With large swathes of land being freed up for new facilities or green spaces, the positive impact on public welfare and countryside habitat health could be significant.

Through analysis of the current state of the industry and projections of its future economic impact, it can be concluded that as cultivated meat reaches ever wider populations, it could generate significant improvements in a variety of areas of modern life.

### Reference List

Animal-Free Science Advocacy. (2013) 'Use of Fetal Calf Serum' Available at: <https://animalfreescienceadvocacy.org.au/fetal-calf-serum/> (Accessed: 29 April 2024).

Cattaneo, G.M., Varotto-Boccazzi, I., Molteni, R., Ronchetti, F., Gabrieli, P., Mendoza-Roldan, J., Otranto, D., Montomoli, E., Bandi, C. & Epis, S. 2024, 'A novel chemically defined medium for the biotechnological and biomedical exploitation of the cell factory *Leishmania tarentolae*', *Scientific Reports (Nature Publisher Group)*, 14(1), pp.9562.

Chowdhury, S., Khan, S., Sarker, M. F. H., Islam, M. K., Tamal, M. A., & Khan, N. A. (2022) 'Does agricultural ecology cause environmental degradation? Empirical evidence from Bangladesh', *Heliyon*, 8(6).

Decc, B. (2020) 'Lab-Grown Meat Isn't Natural-And Neither Is Factory Farming' Available at: <https://sentientmedia.org/lab-grown-meat-isnt-natural-and-neither-is-factory-farming/> (Accessed: 29 April 2024).

Douglas, L. (2023) 'As lab-grown meat hits menus, the next investor hurdle is scaling', REUTERS, Available at: <https://www.reuters.com/markets/commodities/cell-cultivated-meat-hits-menus-investors-see-scaling-next-hurdle-2023-07-20/> (Accessed: 18 March 24).

Duarte Rojas, J.M., Restrepo Múnera, L. M. & Estrada Mira S. (2024) 'Comparison between Platelet Lysate, Platelet Lysate Serum, and Fetal Bovine Serum as Supplements for Cell Culture, Expansion, and Cryopreservation', *Biomedicines*, 12(1), pp.140.

Even, M. S., Sandusky, C. B., & Barnard, N. D. (2006) 'Serum-free hybridoma culture: ethical, scientific and safety considerations.' *Trends in biotechnology*, 24(3), pp.105–108.

Filippin, D., Sarni, A.R., Rizzo, G. & Baroni, L. (2023) 'Environmental Impact of Two Plant-Based, Isocaloric and Isoproteic Diets: The Vegan Diet vs. the Mediterranean Diet', *International Journal of Environmental Research and Public Health*, 20(5), pp.3797.

Gaydhane, M.K., Mahanta, U., Sharma, C.S. Khandelwal, M., & Ramakrishna, S. (2018) 'Cultured meat: state of the art and future'. *Biomanufacturing Reviews*, vol. 3, no. 1.

Gu, D., Andreev, K., & Dupre, M. E. (2021) 'Major Trends in Population Growth Around the World', *China CDC weekly*, 3(28), pp.604–613.

Haldankar, R., Li, D., Saremi, Z., Baikalov, C. & Deshpande, R. (2006) 'Serum-free suspensin large-scale transient transfection of CHO cells in WAVE bioreactors', *Molecular biotechnology*, 34(2), pp.191-9.

Hart, D. and Sussman, R.W. (2018) *Man the hunted: primates, predators, and human evolution*. New York: Routledge.

Harsini, F. & Swartz, E. (2023) 'Trends in cultivated meat scale-up and bioprocessing' Available at: <https://gfi.org/resource/trends-in-cultivated-meat-scale-up-and-bioprocessing/> (Accessed: 05 June 25).

Hopfenberg, R. & Pimentel, D. (2001) 'Human Population Numbers as a Function of Food Supply', *Environment, Development and Sustainability*, 3(1), pp.1.

Hwang, J., You, J., Moon, J., Jeong, J. (2020) 'Factors Affecting Consumers' Alternative Meats Buying Intentions: Plant-Based Meat Alternative and Cultured Meat', *Sustainability*, 12(14).

Jochems C.E., Van Der Valk J.B., Stafleu F.R. & Baumans V. (2002) 'The use of fetal bovine serum: ethical or scientific problem?' *Altern Lab Anim.*, 30(2), pp.219-27.

Jung, E., Kong, S.Y., Ro, Y.S., Ryu, H.H., Shin, S.D. (2022) 'Serum Cholesterol Levels and Risk of Cardiovascular Death: A Systematic Review and a Dose-Response Meta-Analysis of Prospective Cohort Studies', *Int J Environ Res Public Health*. 19(14), pp.8272.

Kirsch, M., Morales-Dalmau, J., & Lavrentieva, A. (2023) 'Cultivated meat manufacturing: Technology, trends, and challenges', *Engineering in life sciences*, 23(12).

Lambert, J., (2011) 'Primate nutritional ecology: Feeding biology and diet at ecological and evolutionary scales.' *Primates in Perspective*. pp.512-522.

Lamoreux M. L. & Bennett D. C., (2024) 'Scientists' Warning on the Problem with Overpopulation and Living Systems', *Journal of Population and Sustainability*, 8(1), pp.95-111.

Lee, D. Y., Lee, S. Y., Yun, S. H., Jeong, J. W., Kim, J. H., Kim, H. W., Choi, J. S., Kim, G. D., Joo, S. T., Choi, I., & Hur, S. J. (2022) 'Review of the Current Research on Fetal Bovine Serum and the Development of Cultured Meat.' *Food science of animal resources*, 42(5), pp.775–799.

Lepak, J.M., Johnson, B.M., Hooten, M.B., Wolff, B.A. & Hansen, A.G. (2023) 'Predicting sport fish mercury contamination in heavily managed reservoirs: Implications for human and ecological health', *PLoS One*, 18(8).

Lewisch, L. & Riefler, P. (2023) 'Cultured meat acceptance for global food security: a systematic literature review and future research directions', *Agricultural and Food Economics*, 11(1), pp.48.

Lorenzo, D. (2023) 'Did Italy Really Withdraw Its Intention To Ban Cultivated Meat?' *Forbes*, October Available at: <https://www.forbes.com/sites/danieladelorenzo/2023/10/20/did-italy-really-withdraw-its-intention-to-ban-cultivated-meat/> (Accessed: 29 Jul 2025).

Mark, P., Kleinsorge, M., Gaebel, R., Lux, C. A., Toelk, A., Pittermann, E., David, R., Steinhoff, G., & Ma, N. (2013) 'Human Mesenchymal Stem Cells Display Reduced Expression of CD105 after Culture in Serum-Free Medium', *Stem cells international*, vol. 2013.

Moya, S.F., Pastrana, C.I., Navas, C.M., Aguilera, J.R., Vicente, J., González, D.B., González, N., Francisco, J. (2022) 'The Winner Takes it All: Risk Factors and Bayesian Modelling of the Probability of Success in Escaping from Big Cat Predation', *Animals*, 12(1), pp.51.

Niemiec, R., Jones M.S., Mertens, A., Dillard, C., (2021) 'The effectiveness of COVID-related message framing on public beliefs and behaviors related to plant-based diets' *Appetite*. 202(165).

Pallaoro, M., Modina, S.C., Fiorati, A., Altomare, L., Mirra, G., Scooco, P. & Giancamillo, A.D. (2023) 'Towards a More Realistic In Vitro Meat: The Cross Talk between Adipose and Muscle Cells', *International Journal of Molecular Sciences*, 24(7), pp.6630.

Reiss, J., Robertson, S., Suzuki, M. (2021) 'Cell Sources for Cultivated Meat: Applications and Considerations throughout the Production Workflow', *Int J Mol Sci*. 22(14), pp.7513.

Santos, A.C.A., Camarena, D.E.M., Reigado, G.R., Chambergo, F.S., Nunes, V.A., Trindade M.A. & Maria-Engler, S.S. (2023) 'Tissue Engineering Challenges for Cultivated Meat to Meet the Real Demand of a Global Market', *International Journal of Molecular Sciences*, 24(7), pp.6033.

Selwyn, M., Lázaro-González, A., Lloret, F., Rey Benayas, J.M., Hampe, A., Brotons, L., Pino, J., Espelta, J.M. (2025) 'Quantifying the impacts of rewilding on ecosystem resilience to disturbances: A global meta-analysis', *J Environ Manage*. 375.

Singh, A., Singh, S.K., Kumar, V., Gupta, J., Kumar, M., Sarma, D.K., Singh, S., Kumawat, M. & Verma, V. (2024) 'Derivation and Characterization of Novel Cytocompatible Decellularized Tissue Scaffold for Myoblast Growth and Differentiation', *Cells*, 13(1), pp.41.

Sugii, S., Cheryl Yeh, Q.W., Angela Khin, O.L. & Lamony Jian, M.C. (2023) 'Alternative fat: redefining adipocytes for biomanufacturing cultivated meat', *Trends in biotechnology*, 41(5), pp.686-700.

Tenev, D. (2022) 'La Déconstruction en enfant: the Concept of Phantasm in the Work of Derrida' Available at: [https://www.academia.edu/81702445/La\\_D%C3%A9construction\\_en\\_enfant\\_the\\_Concept\\_of\\_Phantasm\\_in\\_the\\_Work\\_of\\_Derrida](https://www.academia.edu/81702445/La_D%C3%A9construction_en_enfant_the_Concept_of_Phantasm_in_the_Work_of_Derrida) (Accessed: 30 March 2024).

Thyden, R., Perreault, L.R., Jones, J.D., Notman, H., Varieur, B.M., Patmanidis, A.A., Dominko, T. & Gaudette, G.R. (2022) 'An Edible, Decellularized Plant Derived Cell Carrier for Lab Grown Meat', *Applied Sciences*, 12(10), pp.5155.

Vegconomist. (2023) 'Regulatory Milestone' as GOOD Meat Receives Approval for Serum-Free Cell Growth Media' Available at: <https://vegconomist.com/cultivated-cell-cultured-biotechnology/cultivated-meat/good-meat-approval-serum-free-cell-growth-media/> (Accessed: 29 April 2024).

Warner, R. D. (2019) 'Review: Analysis of the process and drivers for cellular meat production', *Animal : an international journal of animal bioscience*, 13(12), pp.3041–3058.  
Wee, S.Y., Choudhury, D. & Suntornnond, R. (2023) 'Towards biomanufacturing of cultured meat', *Trends in biotechnology*, 41(3), pp.292-294.

Yang, J. (2023) 'Willingness to buy animal welfare products: a study on the conflict between moral attitudes and perceived higher prices', *Journal of Applied Animal Research*, 51(1), pp.447-455.

Yang, J. Skaro, M., Chen, J., Zhan, D., Lyu, L., Gay, S., Kandeil, A., Ali, M.A., Kayali, G., Stoianova, K., Ji, P., Alabady, M., Bahl, J., Liu, L. & Arnold, J. (2023) 'The species coalescent indicates possible bat and pangolin origins of the COVID-19 pandemic', *Scientific Reports (Nature Publisher Group)*, 13(1), pp.5571.

# THE FUTURE OF RENEWABLE ENERGY: MICRO-HYDRO SYSTEMS BENEFITING COMMUNITIES.

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## ABSTRACT

*This paper explores the ability of micro-hydro systems to provide a sustainable and environmentally friendly solution to meet the global demand for reliable, renewable energy. By utilising existing infrastructure micro-hydro systems offer a low-impact alternative to large-scale hydroelectric projects, which can cause significant ecological disruption and social displacement. Micro-hydro projects, especially those using Archimedes Screw Turbines, generate efficient and reliable energy for small communities which is especially beneficial for rural, underserved regions. Case studies of successful projects demonstrate the viability and potential additional benefits micro-hydro brings to communities, including local energy supply and economic uplift. While these projects contribute to energy sustainability, they also support local economies and reduce dependence on fossil fuels. Overall, micro-hydro represents a key component of a cleaner, greener, and more equitable energy future, offering a promising option that can meet the environmental and socio-economic challenges faced in energy production.*

**KEY WORDS:** Micro-hydro, renewable energy, hydroelectric, sustainable, community based.

## INTRODUCTION

Hydropower is the largest source of renewable energy globally (Quaranta *et al*, 2022), having been utilised by civilisations for centuries. Wilson (2002) found that water was utilised throughout the Roman world in the first century AD in lifting devices, power mining and milling grain. An example of this is the Barbegal watermill complex in southern France, which is regarded as the ancient world's first attempt of industrialisation (Sürmelihindi *et al*, 2019). YoosefDoost and Lubitz (2020) found evidence of hydropower being used by the Assyrian Empire as early as the 7<sup>th</sup> century BCE.

Weirs are one of the UK's most widespread methods for channel modification and regulating flow, with their historical importance resulting in many receiving conservation designation (Howard *et al*, 2017).

This paper considers the advantages of utilising existing weirs for electricity generation, focusing on the benefits of micro-hydro Run of River systems compared to larger impoundment projects.

### LARGE SCALE HYDRO PROJECTS

Large hydroelectric projects produce over 10 MW of power, providing electricity to large towns and extensive grids (Harvey, 1993), while supporting water management, improving storage capacity and giving extra flexibility for the grid (Quaranta *et al.*, 2022). For example, the Three Gorges Dam (TGD) in China can produce 22,500 MW when all its generators are in operation (Cheng *et al.*, 2021), supplying power to 80 million homes (Lee & Lee, 2021). However, Ma *et al.* (2017) found that river damming can significantly influence diatoms growth in rivers and reservoirs, substantially affecting nutrient cycles altering the balance of silica. This affects the biogeochemical cycles of carbon, nitrogen and other nutrients which couple with silica. This is evidenced by what Guo *et al.* (2011) found when the TGD operation began, the rate at which sediment was transported was reduced by up to 31 %.

The construction of large Hydro plants can positively impact local economies. Sgarbi *et al.* (2019) demonstrated increased jobs and salaries and the service sector benefited. However, these benefits did not continue long-term unlike the adverse effects the municipalities found in reduced education and fertility rates which, during construction and operation, reduced by 6.62 % and 7.44 % respectively. These changes were postured to be resulting from improved lifestyle and economic opportunities realised by the introduction of the dam (Sgarbi *et al.* 2019). An increase in Malaria cases since the construction of a large dam in Cameroon was observed. Additionally, families were displaced by flooding and a sanitation crisis which occurred in Brazil because of the Belo Monte dam (Mbakop *et al.*, 2019; Gauthier and Moran, 2018).

Santos (2020) found that dams harm local fishery stocks and aquatic ecosystems, stating that changes in fish conditions had been perceived, such as reduced size and weight, irregular breeding patterns and increased exophthalmia. Lee and Lee (2021) generalise this information arguing that wildlife habitats and farmland are lost or damaged by large hydropower schemes, amongst other environmental and social threats to local people. They argue the need for micro-hydro power to be utilised as such risks can be mitigated while still providing power where it is needed.

### MICRO-HYDRO

Micro-hydro schemes produce power within the range of 200 W to 300 kW which is enough to power domestic lighting for a group of homes of small industries connected to a local 'mini grid' (Harvey, 1993; Lee and Lee, 2021). Micro-hydro schemes can improve rural communities, especially in low-income countries, as access to education improves allowing a labour shift to better-paid jobs (Subedi *et al.*, 2023).

Although smaller plants have a lower environmental impact, they must be operated sustainably, ensuring a low impact on ecosystems (Quaranta *et al.*, 2022). Repurposing existing weirs can be part of a sustainable operating method, as their removal risks remobilising contaminants locked within the stationary sediments, which may cause long-term, detrimental health and environmental impacts (Howard, 2017).

When selecting a turbine the site characteristics must be considered, most importantly head height and the required power, while also considering the speed needed for the generator to operate (Harvey, 1993). Thakur (2024) found that when compared to other turbines Archimedes Screw Turbines (AST) are more environmentally and fish friendly being able to offer cleaner and safer renewable energy. Operating with low water heads and high efficiencies (60 % - 80 %) they make more sites suitable to be developed (YoosefDoost and Lubitz, 2020), including regions that are hard to access and small communities in rural areas (Lee and Lee, 2021; Tiwari *et al.*, 2002; Signe *et al.*, 2017). Haikarainen *et al.* (2015) discusses the growing trend of smaller power plants supporting flexibility and improving regional energy security. While being able to quickly bring near-optimal solutions to challenges faced by smaller, rural communities, although each project is individual and require its own solution.

### SIMILAR UNDERTAKEN PROJECTS

This project is inspired by previously completed projects such as the Nethermills Hydro scheme (Energy Agency, 2024), Settle Hydro (Settle Hydro, 2024), Cragside and the Romley weir project that powers Windsor Castle (EcoEvolution, 2013).

Settle Hydro was built in 2009 at the site of a former mill. Since its operation over 1000000 kWh has been produced. This powers the apartments within the mill while excess energy is supplied to the National Grid, the profits of which are distributed to organisations in the local community (Settle Hydro, 2024). Similarly, the Nethermills Hydro scheme began generating electricity in March 2022, producing 321 MWh in the first 12 months. 21 % of the electricity is sold to the grid helping to reduce fuel poverty and raising funds for other projects in the area (Energy Agency, 2024).

Many new developments face opposition, as the Hexham River Hydro team faced while developing their 602 MWh scheme (Hexham River Hydro, 2013). The scheme is now on hold due to soaring costs which have doubled from initial estimates (BBC, 2013), along with environmental and ecological concerns from a local Anglers' Association, a regional Salmon and Trout Conservation and Tyne Rivers Trust (Curry, 2022). Agreeing that Hydropower is beneficial but that the Hexham Bridge location is not suitable and other solutions or locations should be explored (Curry, 2022).

### DERWENTHAUGH WEIR

Considering these challenges, the Derwenthaugh weir section of the Derwent River as it flows through Swalwell, Tyne and Wear, has been chosen to be investigated for this case study as a suitable site. Being close to Swalwell cricket ground and tennis club the power produced can be used to improve their sustainability while excess being provided to the grid in the same way as the Settle Hydro and the Nethermills Hydro scheme (Settle Hydro, 2024; Energy Agency, 2024). In 2013 a Larinier fish pass was fitted to the weir which allows fish to complete their spawning migration up stream, however, this does raise additional challenges for installing a turbine to this location as it was found that the ground under the weir was contaminated due to its industrial history, meaning extra care must be taken during construction to prevent such contamination entering the river (Environment Agency, 2023). Also, while communicating with Jack Bloomer, a project manager with Tyne Rivers Trust, he

informed the researcher that the Larinier fish pass that was fitted on the Derwenthaugh weir required a specific flow rate to operate effectively. This must be considered when working out the potential power available from a turbine. Similar work of installing fish passes has been undertaken on two weirs upstream which may also be worth further investigation for suitability for a hydropower scheme to support local communities (Environment Agency, 2023).

## CONCLUSION

In conclusion, micro-hydro offers a promising sustainable solution to meet the growing demand for renewable energy (Haikarainen *et al*, 2015), especially when integrating existing infrastructure such as weirs (Howard, 2017). Compared to large hydro projects, micro-hydro systems create a significantly smaller environmental footprint, avoiding the considerable ecological disruption and displacement issues associated with large impoundments (Subedi *et al*, 2023). Their ability to generate reliable renewable energy while adapting to the individual needs of small communities or industries make them an attractive alternative for underserved rural regions (Harvey, 1993; Lee and Lee, 2021). Their viability is further enhanced by the low-maintenance and high efficiency of the Archimedes Screw Turbine, which is a proven fish-friendly and environmentally safe method of power generation (Thakur, 2024). The validity of micro-hydro projects can be shown by the proven successful track records of projects like Settle Hydro and the Nethermills scheme, which supply energy to the local community while also benefitting the broader community and supporting the National Grid (Settle Hydro, 2024; Energy Agency, 2024). By focusing on sustainability and community well-being, micro-hydro can play a crucial role in meeting the world's growing energy demands, without compromising the health of local ecosystems or people. Therefore, micro-hydro is key for a cleaner, greener, and more equitable energy future opening the possibility for alternative locations to be investigated for the ability to support energy production and security (Lee and Lee, 2021).

## Reference List

- BBC (2013) *Hexham River Hydro scheme shelved due to cost*, *BBC News*. Available at: <https://www.bbc.co.uk/news/uk-england-tyne-22884896> (Accessed: 18 December 2024).
- Cheng, D. Shi, X. Yu, J. (2021) 'The impact of green energy infrastructure on firm productivity: Evidence from the Three Gorges Project in China', *International Review of Economics and Finance*, 71, pp. 385-406.
- Curry, R. (2022) *Anglers celebrate after Hexham hydropower scheme is shelved following concerns for Tyne's salmon*, *Hexham Courant*. Available at: <https://www.hexham-courant.co.uk/news/23083151.hexham-hydropower-scheme-shelved-concerns-river-tyne-salmon/> (Accessed: 18 December 2024).
- EcoEvolution, (2013) *Romney Weir is turning the screw on CO2*, *Eco Evolution Blog*. Available at: <http://ecoevolution.ie/blog/romney-weir-turning-the-screw-on-co2/> (Accessed: 03 December 2024).

Energy Agency (2024) *Nethermills Hydro Scheme meets expected targets despite unusually dry year*, *Energy Agency*. Available at: <https://www.energyagency.org.uk/nethermills-hydro-scheme-meets-expected-targets-despite-unusually-dry-year/> (Accessed: 03 December 2024).

EnvironmentAgency (2023) *Celebrating a decade's work returning fish to the River Derwent., Creating a better place*. Available at: <https://environmentagency.blog.gov.uk/2023/12/20/celebrating-a-decades-work-returning-fish-to-the-river-derwent/> (Accessed: 18 December 2024).

Gauthier, C. and Moran, E.F. (2018) 'Public Policy implementation and basic sanitation issues associated with hydroelectric projects in the Brazilian Amazon: Altamira and the Belo Monte dam', *Geoforum*,

Guo, H., Hu, Q., Zhang, Q. and Feng, S. (2012) 'Effects of the three gorges dam on Yangtze River Flow and river interaction with Poyang Lake, China: 2003–2008.', *Journal of Hydrology*. 416–41719–27.

Haikarainen, C., Pettersson, F. and Saxén, H. (2015) 'A Spatial Decomposition Procedure for Efficient Solutions of Two-Dimensional Energy Distribution Problems', *Computer-aided chemical engineering*.

Harvey, A. (1993) *Micro-hydro Design Manual: A Guide to small-scale waterpower schemes*. London, UK: Intermediate Technology Publications.

Hexham River Hydro (2013) *Hexham River Hydro*. Available at: <https://hexhamriverhydro.wordpress.com/> (Accessed: 18 December 2024).

Howard, A.J., Coulthard, T.J., and Knight, D. (2017) 'The Potential Impact of Green Agendas on Historic River Landscapes: Numerical Modelling of Multiple Weir Removal in The Derwent Valley Mills World Heritage Site, UK', *Geomorphology*, 293(A), pp. 37-52.

Lee, M.D. and Lee, P.S., (2021) 'Modelling the Energy Extraction from Low-Velocity Stream Water by Small Scale Archimedes Screw Turbine', *Journal of King Saud University - Engineering Sciences*. doi: 10.1016/j.jksues.2021.04.006.

Ma, N., Song, Z., Wang, B., Wang, F., Yang, X., Zhang, X., Hao, Q. and Wu, Y. (2017) 'Effect of River Damming on Biogenic Silica Turnover: Implications for Biogeochemical Carbon and Nutrient Cycles', *Acta Geochimica*, 36, pp. 626-637.

Mbakop, L.R., Awono-Ambene, P.H., Mandeng, S.E., Ekoko, W.E., Fesuh, B.N., Antonio-Nkondjio, C., Toto, J.-C., Nwane, P., Fomena, A. and Etang, J. (2019) Malaria transmission around the memve'ele hydroelectric dam in south cameroon: A combined retrospective and Prospective Study, 2000–2016. *International Journal of Environmental Research and Public Health*. 16 (9), 1618.

Quaranta, E., Bódis, K., Kasiulis, E., McNabola, A. and Pistocchi, A. (2022) Is there a residual and hidden potential for small and micro hydropower in Europe? A screening-level regional assessment. *Water Resources Management*. 36 (6), 1745–1762.

Santos, R.E., Pinto-Coelho, R.M., Drumond, M.A., Fonseca, R. and Zanchi, F.B. (2020) 'Damming Amazon Rivers: Environmental Impact of Hydroelectric Dams on Brazil's Madeira River According to Local Fishers' Perception', *AMBIO*.

Settle Hydro (2024) *Settlehydro.org.uk settle Hydro - a pioneering, community-owned, hydroelectric scheme*. [Online] [online]. Available from: <https://www.settlehydro.org.uk/> (Accessed 2 December 2024).

Sgarbi, F. de.A., Uhlig, A., Simões, A.F. and Goldemberg, J. (2019) 'An assessment of the socioeconomic externalities of hydropower plants in Brazil.' *Energy Policy*. 129868–879.

Signe, E.B.K., Hamandjoda, O. and Nganhou, J. (2017) 'Methodology of Feasibility Studies of Micro-Hydro Power Plants in Cameroon: Case of the Micro-Hydro of Kemken' *Energy Procedia*.

Subedi, M.N., Bharadwaj, B. and Rafiq, S. (2023) 'Who benefits from the decentralised energy system (DSE)? Evidence from Nepal's micro-hydropower (MHP)', *Energy Economics*.

Sürmelihindi, G., Passchier, C.W., Leveau, P., Spötl, C., Bourgeois, M. and Bernard, V. (2019) 'Barbegal: carbonate imprints give a voice to the first industrial complex of Europe', *Journal of Archaeological Science: Reports*, 24, pp. 1041-1058.

Thakur, R., Kashyap, T., Kumar, R., Saini, R.K., Lee, D., Kumar, S. and Singh, T., (2024) 'Potential of the Archimedes Screw to Generate Sustainable Green Energy for Mini, Micro and Pico Hydro Turbine Power Stations: An Extensive Analysis', *Energy Strategy Reviews*,

Tiwari, S. *et al.* (2002) 'Design & Fabrication of Archimedes Screw Turbine', *International Conference on Science, Engineering and Technology*.

Wilson, A. (2002) 'Machines, Power and the Ancient Economy', *Journal of Roman Studies*, 92, pp. 1–32. doi:10.2307/3184857.

YoosefDoost, A. and Lubitz, W. (2020) 'Archimedes screw turbines: A sustainable development solution for green and renewable energy generation—a review of potential and design procedures', *Sustainability*, 12(18), pp. 7352. Available at: <https://doi.org/10.3390/su12187352>.

# Is the net effect of increased social media usage amongst adolescents increased narcissism?

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## **ABSTRACT**

*This study aims to understand the relationship between social media use and the development of narcissistic tendencies amongst adolescents. It explores several themes to gain a better understanding of psychological risks of narcissism, the correlation between social media usage and narcissism, and if cultural differences play a role in this relationship too. The research is conducted through secondary methods, analysing key articles relevant to the study's focus. Three key articles recognise these themes: Fegan and Bland explore the correlation between social media and vulnerable narcissism, Mas-Manchon and Davila investigate cultural differences within social media, and Peris et al. highlight the psychological impact of narcissism on adolescent. Findings found that adolescents with pre-existing vulnerable narcissistic traits are more prone to social media addiction. These findings align with Bandura's social learning theory, which suggests adolescents mimic behaviours of those with a higher social status for self-validation. The findings within this study suggest that more targeted support needs to be put in place to help adolescents at risk of adopting narcissistic.*

**KEYWORDS:** Grandiose narcissism, vulnerable narcissism, adolescents, intervention, social media

## **INTRODUCTION**

Narcissism and social media has received a lot of scholarly attention through research, highlighting the want to understand what the links are between increased social media usage and narcissistic traits. This study will be looking into the primary social media platforms that are used within contemporary society such as Facebook, Instagram, TikTok and Twitter, whilst also gaining an understanding of which of these platforms tend to emphasise the importance of self-presentation or validation. Additionally, this study will also include research on the complexity of narcissism amongst adolescents and how it should not be viewed as a singular dimension, but an expansive psychological trait that will affect certain individuals in complex ways. Whilst the primary aim of this study is to look into this relationship, it will also aim to gain a more in-depth understanding on the growing concern of the rising usage of social media amongst adolescents and how there is an increasing risk of negative influences impacting their personality development (Miller *et al.*, 2017).

Although the primary research of this study is “the net effect of increased social media usage amongst adolescents increased narcissism”, there will be secondary objectives set to act as a foundation to answer the key question with high quality research and a theoretical framework that will guide the research involved. Terrell (2022) states that by including secondary objectives this can act as a road map for the researcher to start the journey from the problem statement to the conclusion in reliable manner that acknowledges the research problem, purpose and question. Some of the objectives will include:

- Assess if different narcissistic traits vary on different social media platforms.
- Do likes and comments on social media posts correlate with self-validation seeking behaviours?
- Identify if parental guidance and social media support programmes mitigate narcissistic behaviours.

This study will play a role in recognising the effects that narcissism can have on adolescents and the kinds of support that can be put in place to help those at risk of being easily influenced by negative factors found on social media platforms. Furthermore, it will provide a better insight of psychological and sociological theory relative to social media and narcissism that will also fill in gaps of research that has not yet been answered by previous pieces of literature (Joyner, Rouse and Gathorn, 2018). As social media plays such a significant role within society amongst adolescents, the findings within this study can be used to contribute to more sensitive topics that needs to be addressed within contemporary society. Additionally, policy makers may be able to use this study to develop more supportive campaigns that will promote how social media can be used more safely and risks can be avoided, creating more healthier digital habits.

### **LITERATURE REVIEW**

While there is a considerable amount of information that shows the evident rise in social media and the complex state of narcissism, there are still many gaps to be filled, for example do all social media platforms result in the same form of narcissism and if current personality traits moderate the link between social media and narcissism. Recognising these gaps in knowledge can lead to accurate results being built, stronger methodologies implemented, and more meaningful conclusions can be created which add to the knowledge that has previously been published (Wald, Harland and Daskon, 2024).

There is a wide range of secondary research which supports the topic of this study, offering a structured overview of the key question. For instance, Casale and Banchi (2020) highlight a link between narcissism and the increasing level of addictive social media use. In the UK, Facebook had approximately 1.6 million users aged 13–17 in June 2023, up from 750,000 in April 2022 (Statista, 2023). However, the research is limited as it heavily relies on cross-sectional studies, creating barriers and making it more difficult to determine the causation between social media use and narcissistic traits in adolescents.

Contemporary, historical psychological and sociological theories can be applied to the theoretical framework to critically analyse data from secondary research. For example, the

Uses and Gratification theory suggests adolescents use social media for self-validation and social admiration, reinforcing narcissistic traits as they seek to influence others' perceptions (Rui and Stefanone, 2016). However, while this theory highlights the entertainment-driven influence of social media, it overlooks external pressures, such as peer influence or societal expectations which may further compel adolescents to use these platforms.

In contrast to the self-driven motives in Katz *et al.* Uses and Gratification theory, Perkins and Berkowitz's Social Norms theory adopts a sociological lens, suggesting adolescents' online behaviour is shaped by exaggerated social group norms (Angelini *et al.*, 2024). This theory emphasises conformity to perceived social expectations, as social norms coordinate behaviour to align with others (McDonald and Crandall, 2015). For instance, on platforms like TikTok, adolescents often display exaggerated behaviours to gain validation, reflecting what is considered popular on what is known as the "fun platform" (Barta and Andalibi, 2021). However, the theory overlooks the mental health impact of these social pressures and the impacts this can have on an adolescent's wellbeing.

Considering both sociological and psychological theory this allows for a more comprehensive understanding on how social media is a constantly evolving part of society that needs to have an ontological perspective on it by using theory that can adapt to complex social phenomena (Power *et al.*, 2023). Using psychological or sociological theory is beneficial for this study as it is recognised as a principle of knowledge gathered through scientific research that explains phenomenon within society (Payne, 2022).

James *et al.* (2017) noted that social media's influence on adolescents has grown due to ongoing technological advancements and evolving platforms. However, further research is needed to understand how specific platforms like Instagram or TikTok differently impact adolescent narcissistic traits and how to better support those who are deemed as being a higher risk. Kong *et al.* (2021) found that platforms like Facebook and Twitter are linked to vulnerable narcissism, as adolescents seek validation but often lack emotional support, increasing their desire for attention. In contrast, TikTok is more associated with grandiose narcissism, where adolescents pursue virality and self-promotion through performance (Derry, Ohan & Bayliss, 2020). While such platforms encourage creativity and boldness, they also pose risks by promoting exaggerated confidence, wealth display, and attention-seeking behaviours.

Orben (2020) highlights that while research acknowledges social media's psychological effects on youth, such as mental health issues or addiction, it often lacks detail on the processes and long-term impacts on cognitive development and social behaviour. Much of the psychological and sociological theory in secondary research is outdated or lacks relevance, reducing its reliability in the context of modern social media. This is further supported by Fegan and Bland (2021), who argue that narcissism is often oversimplified as a cause-and-effect issue, despite its complexity and the existence of distinct types, such as grandiose and vulnerable narcissism.

An individual with grandiose narcissism is characterised as being someone with exaggerated levels of self-importance, often also having low levels of empathy and can be emotionally

blunt towards people who they see as less privileged. However, individuals with vulnerable narcissism, are more introverted and may have more fragile levels of self-esteem, they are more prone to emotional distress leading to anxiety and depression. Although both forms of narcissism are significantly different, there is still comparisons that can be made, they both share similar traits in relation to interpersonal antagonism (Weiss and Miller, 2018). For example, both forms of narcissism have traits such as entitlement, someone with grandiose narcissism may believe they deserve to be given special treatment, however vulnerable narcissists form of entitlement is much more covert and they see themselves as being overlooked and underappreciated.

Although secondary research offers extensive insight into the negative effects of social media on adolescents and its link to narcissistic traits, it remains limited in scope. Nesi (2020) notes that while key questions are explored regarding the evolution and impact of social media on youth, there is a lack of connection between causes and effects. Most studies rely on quantitative data, which helps track usage trends but falls short in explaining the connection between both entities and recognising the psychological or sociological processes behind adolescent behaviour. Incorporating more qualitative data, as suggested by Yardley and Bishop (2017), would enable deeper analysis within theoretical frameworks and offer a clearer understanding of how social media allows adolescence to foster problematic narcissistic traits.

Larsen and Adu (2021) note that while many studies highlight a link between social media and narcissistic traits, few incorporate theoretical frameworks, making the research appear less cohesive and harder to relate to key questions. Although prior research has examined the positive and negative impacts of social media on adolescents and their potential development of narcissistic traits (Rao and Kalyani, 2022), important gaps remain. Evidently, while the growing popularity of social media is well-documented, further studies are needed to understand why adolescents are so attracted to these social media platforms in the first place.

## **DISCUSSION**

There is a significant interest regarding the correlation between addictive social media use and narcissistic traits amongst adolescents due to the multitude of academic literature and studies aiming understand this complex relationship. This section explores this relationship and fills in the gaps of knowledge that other studies have missed, by also using a theoretical framework to obtain a better psychological and sociological perspective into this topic.

It is important to gain a critical understanding of the effects that narcissism can have on adolescents' health, especially in the world of social media where most of their life is contained within these social media platforms and networks. Furthermore, with the use of ontology this will help to interconnect certain sociological and psychological factors that are already out there such as social media or narcissism and how much of an effect they can have on an adolescent's life in terms of behavioural changes and cognitive development (Guyon *et al.*, 2019). Grossman (2019) states that ontology's primary focus is recognises what really exists and everything is categorised into facts, objects, or property, taking on a much more realist view as it argues that physical entities still exist regardless of human perception or

conceptualisation. In relation to this, this means social media can be recognised as a conceptual framework that is defined by its structure and functions within society, which also contains a multitude of dimensions that explain the role social media plays within contemporary society (Grossman, 2019).

Increased social media use is linked to psychological effects in adolescents, particularly the development of narcissistic traits. Peris *et al.* (2020) found that heavy usage can amplify both grandiose and vulnerable narcissism, especially in those with existing cognitive vulnerabilities. These findings are supported by Twenge and Campbell's (2015) narcissism epidemic theory, which ties rising narcissism to Western cultural shifts and social media use. Additionally, Wise and Robbie (2020) argue that the dopamine reward from likes and comments can create an addictive cycle, reinforcing narcissistic behaviours and sensitivity to social rejection.

Arguably, Kohut's theory of adaptive narcissism states that narcissism is a natural and safe phenomenon that an adolescent can experience as it allows them to develop their self-confidence or esteem and become a lot more resilient to criticism found on social media (Afek, 2025). Likewise, this correlates with Mas-Manchon and Davila's findings arguing that social media can be used as a productive tool to further develop on their cognitive skills or behaviours and use social media as a positive strategy that will support them rather than negatively impact their mental health (Mas-Manchon and Davila, 2022).

In contrast, adaptive narcissism is a significant negative factor found within social media, as adolescents can easily be influenced by those who may be seen as influential role models found on media platforms such as Instagram or TikTok. Influencer culture plays a big part in adolescents' lives as they are constantly observing how people live on these social media platforms. They see them as inspirations and mimic how they act or behave online as they believe this is what the new social norm is and it will gain them self-validation or recognition from those who are deemed as more popular (Jabeen, Gerritsen and Treur, 2020). In comparison, Fegan and Bland's findings identify that adolescents that have vulnerable narcissism are more likely to be influenced by individuals that they recognise as being inspirational or socially successful. They will start to be observant of these influential behaviours that they believe will earn them a significant increase in social status, as influencers will state this is the main way of being popular by selling products that are seen as trendy or using language that they will know will connect with adolescents' vulnerabilities even if the information is false (McCain and Campbell, 2018).

Bandura's social learning theory reinforced that adolescents are more than likely going to imitate exaggerated social behaviours if they are positively reinforced by peers, however this can lead to feelings of emotional insecurity or oversensitivity if they are not being rewarded for changing to these trendy acceptable norms (Bandura and Hall, 2018). Additionally, they highlight that adolescents are going to be more attracted to influencers that are deemed as more popular or successful, and adolescents that are lot more emotionally vulnerable are going to completely change their personal traits and behaviours to vicariously live through individuals with a more glamorous social status (Bandura and Hall, 2018).

However, whilst this theory does support these findings, it does not consider that narcissism can start to develop before an adolescent begins to use social media, for example the nature versus nurture debate needs to be considered to gain a better understanding of this phenomenon. Although the social learning theory supports the nurture argument that behaviours and personality traits can be learnt through the observation of how people perform. Allport's trait theory takes on a much more nature perspective as Diener and Lucas, (2019) highlight how the trait theory defines narcissism as being a core personality trait that can be the cause of genetic or psychological factors. This can lead to individuals having a lack of empathy for other people as they have significant levels of self-love, resulting into feeling of selfishness or becoming self-entitled (Diener and Lucas, 2019).

Furthermore, the Uses and Gratifications theory, offers a better insight into the relationship between social media use and adolescents, for instance this theory recognises that adolescents will begin to use social media platforms to follow contemporary societal norms and to connect with peer and create new friendships. Additionally, some adolescents may use it to help with personal issues such as loneliness or boredom, as they can use social media to experiment new ways of expressing themselves or share posts of them taking part in new trends (Ferris and Hollenbaugh, 2021). However, this can lead to creating major disruptions within an adolescents' life, such as interfering with sleeping patterns which can create barriers for their cognitive functions, social skills will begin to deteriorate due to spending less time around others and they may begin to feel more pressured to take part in new trends and events due to feeling of FOMO (Fear of Missing Out).

Throughout the process of understanding these key articles, it is clear to see that better support needs to be put in place to protect adolescents on social media platforms, such as promoting healthier lifestyles that can reduce the impacts of addictive social media use and help adolescents understand how to reduce the pressure on having to engage on social media platforms just to feel socially accepted or self-validated (Shaw *et al.*, 2015). During this stage of an adolescent's life, they are completely focused on crafting a self-image that will gain them recognition, aligning with Mas-Manchon and Davila's study that social media can be viewed as a two-way mirror where adolescents present themselves for other people as they believe they are continuously being observed by others. Piaget's cognitive development theory recognises this concept as an adolescent performing for an 'imaginary audience', Dasen (2022) also states this theory suggests that the basic process of observation is universal, however the cognitive thinking styles that are implement are completely reliant influenced by the culture and behaviours surrounding the adolescent (Dasen, 2022).

However, the cognitive development theory can also be used as a support model as it recognises that adolescents are in the formal operational stage of their lives, meaning they start to think more independently, using critical thinking skills and developing their problem-solving skills. By implementing a wide range of interventions, adolescents can be educated in creative ways on how to keep themselves safe on social media platforms, for example Piaget's cognitive development theory encourages activities such as peer interaction, as encouraging adolescents to take part in group activities allows them the opportunity to make new friends in a natural way further increasing their social skills and self-confidence

(Prasetyo, 2020). Furthermore, social media platforms could start implementing new features targeted towards adolescence offering them advice on how to reduce screen time, how to support themselves through stressful situations such as loneliness or depression and information on educational programmes that teach them the risks of unhealthy social media habits.

The findings from all three articles have all played their own role in terms of answering the key question as they are relative to the field of study, and they all take on a different perspective that helps to reinforce and build an argument that can create a hypothesis which provides a better understanding of the relationship between social media and narcissism amongst adolescents. The primary aim of this study was to explore if the net effect of increased social media usage amongst adolescents is increased narcissism, and using these finding has helped to achieve a result that answers the question, due to each study offering a useful insight into the topic of narcissism amongst adolescents.

To summarise, each study provides their own unique perspective into the relationship between social media and narcissism, providing a helpful contribution to the evidence base of the key question, for example Fegan and Bland, (2021) found that adolescents with more vulnerable narcissistic traits are more attracted to using social media as a means of gaining self-validation, however they are more likely to be much more sensitive to negative feedback from peers. Whereas Peris *et al.* (2020) built on this by exploring the idea that social media acts as reinforcer for narcissistic traits that have already have pre-developed by adolescents and not as the main factor of causing narcissism. However, Mas-Manchon and Davila used a epistemological research to gain a deeper understanding of social media, (2022) and found that social media can be perceived as two-way mirror for narcissism in adolescents as intense use of social networking sites can lead to narcissistic traits if they are continuously using it to both create the ideal personal identity and observe others perceptions of these changes. Further questioning the reality of social media and taking on a truth versus perception viewpoint to question the authenticity of ontological views of social media and narcissism.

However, due to these articles all being cross-sectional studies it still raises many questions needing to be answered to gain a further understanding of the problem, as using this form of study creates barriers in terms of wanting to fully understand the long-term effects of addictive social media use and the impacts narcissism can have on an adolescent's cognitive development. Additionally, with the constant evolution of new social media platforms and trends, the data from cross-sectional studies becomes outdated at a much quicker rate, which creates more limits when wanting to explore the ongoing relationship between different social media platforms and different forms of narcissism such as grandiose or vulnerable (Caruana *et al.*, 2015). By using longitudinal research, a better understanding of the causal relationship between these two entities, also gaining further insight into why it is adolescent begin to use social media platforms. Finally, none of the articles highlight how narcissism can evolve with an adolescent, they see it as a singular problem that sticks with them for the rest of their lives, and there needs to be further exploration into how intervention can allow adolescents to adapt to these feeling of narcissism and mitigate the psychological risks of narcissism.

## CONCLUSION

By exploring theoretical frameworks within the field of psychology and sociology in the context of this question, the research within this study was able to fully explore the relationship between the two entities and gain a better understanding of the two entities. The findings within this study have been used to reach an in-depth hypothesis that highlights whilst increased time spent on social media can lead to significant levels of vulnerable narcissism, the relationship is considerably stronger with adolescents that already a pre-disposition to the trait. Cultural differences also play a role in this relationship, as cultures who follow much more individualistic behaviours are more likely to have traits of grandiose narcissism and egocentricity.

Whilst this study has achieved its primary aim, it still comes with some limitations that can be improved with some recommendations for further research. As this study primarily gained information from secondary research that included information from self-reported data there was the issue some of the information may have been biased, which can conflict with the final result. Furthermore, the studies used were all gathered from cross-sectional methods, meaning it will become outdated much quicker, creating limitations for researchers that may want to use this study for further research.

## RECOMMENDATIONS

Within further research, a longitudinal study needs to be implemented to gain a better understanding of the effect of social media on adolescents' overtime in terms of their cognitive development. It is recommended that more data is gathered through methods of primary research, as more authentic responses can be gathered from adolescents, also gaining a much more personal and emotional insight into the affects that social media is having on them. Finally, more contemporary theories need to be explored, so that better support models can be introduced which will mitigate the risks of adolescents adopting significant narcissistic traits, further leading to a negative impact on their mental health.

By providing a further insight on the relationship between social media and adolescents, this study highlights the need for more supportive resources to be put in place such as educational programmes, peer support groups, and screen free zones within schools. Implementing these resources can promote healthier styles for adolescents in a society that is starting to rely on social media networks to function in everyday life. Furthermore, adolescents may feel more open to ask for help if it is easily, leading them to feel more confident and not have to foster narcissistic traits to feel self-validated.

## REFERENCES

Afek, O. (2025) *Psychoanalysis Through the Lens of Narcissism*. New York: Taylor & Francis.

Angelini, F., Gini, G., Marino, C. and Van Den Eijnden, R., (2024) 'Social Media Features, Perceived Group Norms, and Adolescents' Active Social Media Use Matter for Perceived Friendship Quality.', *Frontiers in Psychology*, 15, p.122

Bandura, A. and Hall, P., (2018) 'Albert Bandura and Social Learning Theory.'. *Learning Theories for Early Years*, 78, pp.35-36.

Barta, K. and Andalibi, N., (2021) 'Constructing Authenticity on TikTok: Social Norms and Social Support on the "Fun" Platform.', *Proceedings of the ACM on Human-Computer Interaction*, 5, pp.1-29.

Campbell, K.W. and Twenge, J.M., (2015) *The Wiley Handbook of Psychology, Technology, and Society*, West Sussex: John Wiley and Sons.

Caruana, E.J., Roman, M., Hernández-Sánchez, J. and Solli, P., (2015) 'Longitudinal Studies.', *Journal of Thoracic Disease*, 7(11), p.537.

Casale, S. and Banchi, V., (2020) 'Narcissism and Problematic Social Media use: A Systematic Literature Review.', *Addictive Behaviours Reports*, 11, p.100-252.

Dasen, P.R., (2022) 'Culture and Cognitive Development.', *Journal of Cross-Cultural Psychology*, 53(7-8), pp.789-816.

Diener, E. and Lucas, R.E., (2019) 'Personality Traits.', *General Psychology: Required Reading*, 278, pp. 275-297.

Fegan, R.B. and Bland, A.R., (2021) 'Social Media Use and Vulnerable Narcissism: The Differential Roles of Oversensitivity and Egocentricity.', *International Journal of Environmental Research and Public Health*, 18(17), p.p.9172.

Grossmann, R., (2019) *The Existence of the World: An Introduction to Ontology.*, Oxfordshire: Routledge.

Guyon, H., Kop, J.L., Juhel, J. and Falissard, B. (2018) 'Measurement, Ontology, and Epistemology: Psychology Needs Pragmatism-Realism.', *Theory & Psychology*, 28(2), pp.149-171.

Jabeen, F., Gerritsen, C. and Treur, J., (2020) 'Narcissism and Fame: A Complex Network Model for the Adaptive Interaction of Digital Narcissism and Online Popularity.', *Applied Network Science*, 5, pp.1-31.

James, C., Davis, K., Charmaraman, L., Konrath, S., Slovak, P., Weinstein, E. and Yarosh, L., (2017) 'Digital Life and Youth Well-Being, Social Connectedness, Empathy, and Narcissism.', *Paediatrics*, 140, pp.71-75.

Joyner, R.L., Rouse, W.A. and Glatthorn, A.A., (2018) *Writing the Winning Thesis or Dissertation: A Step-by-Step guide*. Thousand Oaks: Corwin press.

Larsen, H.G. and Adu, P., (2021) *The Theoretical Framework in Phenomenological Research: Development and Application*. Oxfordshire: Routledge.

Mas-Manchón, L. and Badajoz Dávila, D., (2022) The Use of Social Media as a Two-Way Mirror for Narcissistic Adolescents from Austria, Belgium, South-Korea, and Spain. *PloS one*, 17(8), pp. 272-868.

McCain, J.L. and Campbell, W.K., (2018) 'Narcissism and Social Media Use: A Meta-Analytic Review.', *Psychology of Popular Media Culture*, 7(3), p.308.

McDonald, R.I. and Crandall, C.S., (2015) 'Social Norms and Social Influence.', *Current Opinion in Behavioural Sciences*, 3, pp.147-151.

Miller, J.D., Lynam, D.R., Hyatt, C.S. and Campbell, W.K., (2017) 'Controversies in Narcissism.', *Annual Review of Clinical Psychology*, 13(1), pp.291-315.

Nesi, J., (2020) 'The Impact of Social Media on Youth Mental Health: Challenges and Opportunities.', *North Carolina Medical Journal*, 81(2), pp.116-121.

Payne, M., (2020) *Modern Social Work Theory*. London: Bloomsbury Publishing.

Peris, M., Usue de, I.B., Schoeps, K. & Montoya-Castilla, I. (2020) 'Psychological Risk Factors that Predict Social Networking and Internet Addiction in Adolescents', *International Journal of Environmental Research and Public Health*, 17(12), pp. 45-98. Doi: <https://doi.org/10.3390/ijerph17124598>

Power, S.A., Zittoun, T., Akkerman, S., Wagoner, B., Cabra, M., Cornish, F., Hawlina, H., Heasman, B., Mahendran, K., Psaltis, C. and Rajala, A., (2023) 'Social Psychology of and for World-Making.', *Personality and Social Psychology Review*, 27(4), pp.378-392.

Prasetyo, S. (2020) "Analysis of Piaget-Anderson Theory in Learning Modern Economy", *IOP Conference Series. Earth and Environmental Science*, 485(1). Doi: <https://doi.org/10.1088/1755-1315/485/1/012100>.

Rao, B.N. and Kalyani, V., (2022) 'A Study on Positive and Negative Effects of Social Media on Society.', *Journal of Science & Technology (JST)*, 7(10), pp.46-54.

Rui, J.R. and Stefanone, M.A., (2016) 'The Desire for Fame: An Extension of Uses and Gratifications Theory.', *Communication Studies*, 67(4), pp.399-418.

Shaw, J.M., Mitchell, C.A., Welch, A.J. and Williamson, M.J., (2015) 'Social media Used as a Health Intervention in Adolescent Health: A Systematic Review of the Literature.', *Digital Health*, 1, p.205.

Statista., (2023) *Number of Teen Users of Facebook, Messenger, and Instagram in the United Kingdom (UK) as of June 2023*. (Available: [UK teen Facebook, Messenger, and Instagram users 2023 | Statista](#)). (Accessed: 08/02/2025).

Terrell, S.R., (2022) *Writing a Proposal for your Dissertation: Guidelines and Examples*. New York: Guilford Publications.

Wald, N., Harland, T. and Daskon, C., (2024) 'The Gap Statement and Justification in Higher Education Research: An Analysis of Published Articles.', *European Journal of Higher Education*, 14(2), pp.308-323.

Weiss, B. and Miller, J.D., (2018) Distinguishing Between Grandiose Narcissism, Vulnerable Narcissism, and Narcissistic Personality Disorder., 1, *Handbook of Trait Narcissism: Key Advances, Research Methods, and Controversies*, pp. 3-13.

Wise, R.A. and Robble, M.A., (2020) 'Dopamine and Addiction.', *Annual Review of Psychology*, 71(1), pp.79-106.

Yardley, L. and Bishop, F.L., (2017) *Mixing Qualitative and Quantitative Methods: A Pragmatic Approach*. California: Sage Publications.



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ISSN 2516-7219