

Dark sky educational outreach through art and collaboration

Muhammad Rayan Khan
Cosmic Tribe
m.rayankhan@cosmict.org

Keywords:
Dark Skies, Interdisciplinary, Light Pollution, Public Engagement, STEAM

Contemporary assessments reveal the widespread repercussions of light pollution, impacting 99% of the population in the United States and Europe (Falchi *et al.*, 2016). In Pakistan, a study employing satellite remote sensing and GIS techniques exposed the challenges posed by artificial light sources, impeding the nation's potential to establish Dark Sky Places (Butt, 2012). Over the seven-year period from 2012 to 2019, the city of Lahore witnessed a nearly 25% escalation in light pollution, affecting more than 50% of the city, emphasising the importance of government and public initiatives for mitigation (Nisar *et al.*, 2022). This article asserts the critical need for effective measures to mitigate light pollution, positioning Pakistan as a distinguished destination for Dark Sky Places. Regrettably, a deficiency in awareness exacerbates light pollution in the region (Stare, 2022). Urgent and robust awareness initiatives are imperative to underscore the value of preserving natural darkness. This interdisciplinary examination delves into methodologies fostering public awareness of dark sky protection, emphasising their substantial impact on conveying the severity of light pollution, engaging diverse audiences, and garnering support for policies safeguarding the dark sky (e.g., Sleigh & Craske, 2017).

Introduction:

Light pollution, characterised by the excessive use of artificial light that disrupts natural light patterns, has become a pressing global issue with far-reaching consequences. It affects human health and well-being and significantly impacts wildlife and astronomy (e.g., Morand & Lajaunie, 2019). The issue is particularly pronounced in megacities like Karachi, Pakistan, with approximately 17 million people (Zia *et al.*, 2022). Figure 1 compares the population density with the distribution of light pollution in Karachi, Pakistan. This reveals the interplay between human settlement and artificial light emissions. The population density map of Karachi showcases dense concentrations of people in areas like the city centre, along major transport corridors, and in residential clusters. The effects of light pollution include disruptions to ecosystems, alteration of natural habitats and migration patterns, interference with circadian rhythms in humans and animals, and hindrance to astronomical observations (e.g., Falchi *et al.*, 2016).

Addressing light pollution requires effective public engagement strategies that can capture the attention of diverse audiences and raise awareness about its implications (e.g., Nisbet, 2009). However, traditional methods often struggle to reach broad segments of the population due to the complexity of the topic and competing

priorities for public attention (e.g., Offe, 2019). This necessitates exploring innovative approaches that combine scientific knowledge with artistic creativity to engage and educate the public (e.g., Gauntlett, 2007).

Interdisciplinary collaborations between science and art have emerged as a powerful tool for public engagement on complex scientific issues such as light pollution

(Pérez *et al.*, 2021). These collaborations leverage the strengths of both disciplines to create impactful experiences that resonate with people on an emotional and intellectual level (e.g., Lasker & Weiss, 2003). By integrating creative storytelling, visual arts, and interactive experiences, artist-scientist collaborations can communicate scientific concepts in accessible and engaging ways (e.g., Wynne, 2006).

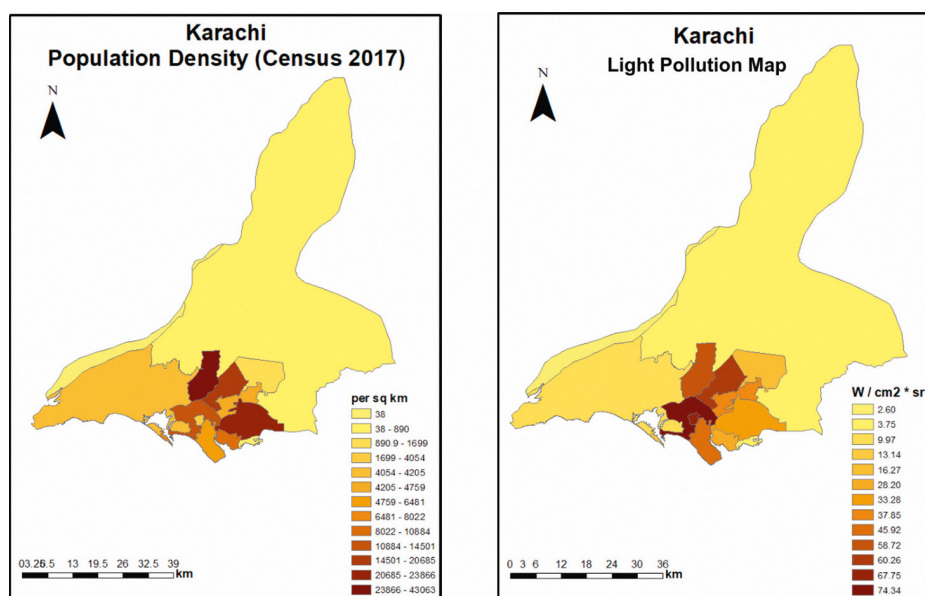


Figure 1: (Left) A map of the population density of Karachi. (Right) A map of the light pollution distribution in Karachi. Image Credit: Muhammad Aly Gajani

One of the key benefits of interdisciplinary public engagement initiatives is their ability to foster dialogue and trust between scientists and the public. By providing opportunities for interaction and discussion, these initiatives empower individuals to ask questions, express concerns, and contribute to informed decision-making processes (e.g., Pace *et al.*, 2010). These collaborative approaches enhance public understanding of scientific issues and strengthen the foundation of democratic societies by promoting transparency and accountability in science communication (e.g., Stilgoe *et al.*, 2014).

This article delves into the need for innovative approaches, particularly interdisciplinary collaborations between art and science, to effectively engage the public on light pollution issues. Through three distinct examples of art/science collaborations, this article explores the power of such initiatives in raising awareness and advocating for dark sky preservation.

This article will discuss three specific examples of interdisciplinary collaborations integrating art and science to address light pollution. These examples showcase the diverse strategies and creative approaches that can be employed to engage and educate the public on the importance of preserving natural darkness.

Dark Sky Superhero: A Collaborative Journey Toward Dark Sky Advocacy

This initiative introduces a superhero character, the Light Pollution Fighter, designed to raise awareness and initiate discussions on light pollution using creative storytelling and sustainable art practices.

Unveiling the Dark Sky Defender: Bridging Art and Science to Combat Light Pollution

Drawing inspiration from the real-life Light Pollution Fighter, we created the 3D animated character, the Dark Sky Defender. This represents a fusion of art and science to communicate the harmful effects of light pollution and promote sustainable lighting practices. Inspired by a physical costume designed for the Dark Sky Superhero character, this animated representation extends the impact of interdisciplinary collaboration in raising awareness

about light pollution and advocating for environmental conservation.

Collaborative Storytelling with Luke Kornis

A collaborative travelogue project with Luke Kornis, a prominent YouTube influencer, showcases Pakistan's landscapes while highlighting the impact of light pollution and advocating for dark sky preservation.

These initiatives demonstrate the power of interdisciplinary collaborations in conveying complex scientific concepts and fostering public understanding and action.

Enhancing public scientific literacy via imaginative collaborations.

As Owen *et al.* (2013) assert, adopting an interdisciplinary framework for public engagement with science offers numerous advantages. Such an approach helps to clarify and explain intricate subjects,

including light pollution, for individuals lacking specialised expertise while concurrently fostering a bilateral exchange of ideas between scientists and the public. Additionally, it introduces novel perspectives on research and potential resolutions.

Nevertheless, MacLeod (2018) articulated that interdisciplinary methodologies are not without challenges. Striking an equilibrium between diverse disciplines can be difficult, and divergent viewpoints regarding the optimal means of communicating scientific concepts to the general public may arise. However, these should not dissuade communicators from pursuing innovative methods in science engagement.

Figure 2 visually explains the inherently intersectional nature of light pollution based on the framework outlined in Hölker *et al.* (2010). Their article describes the intrinsic value of collaborations extending beyond scientific domains involving policy and

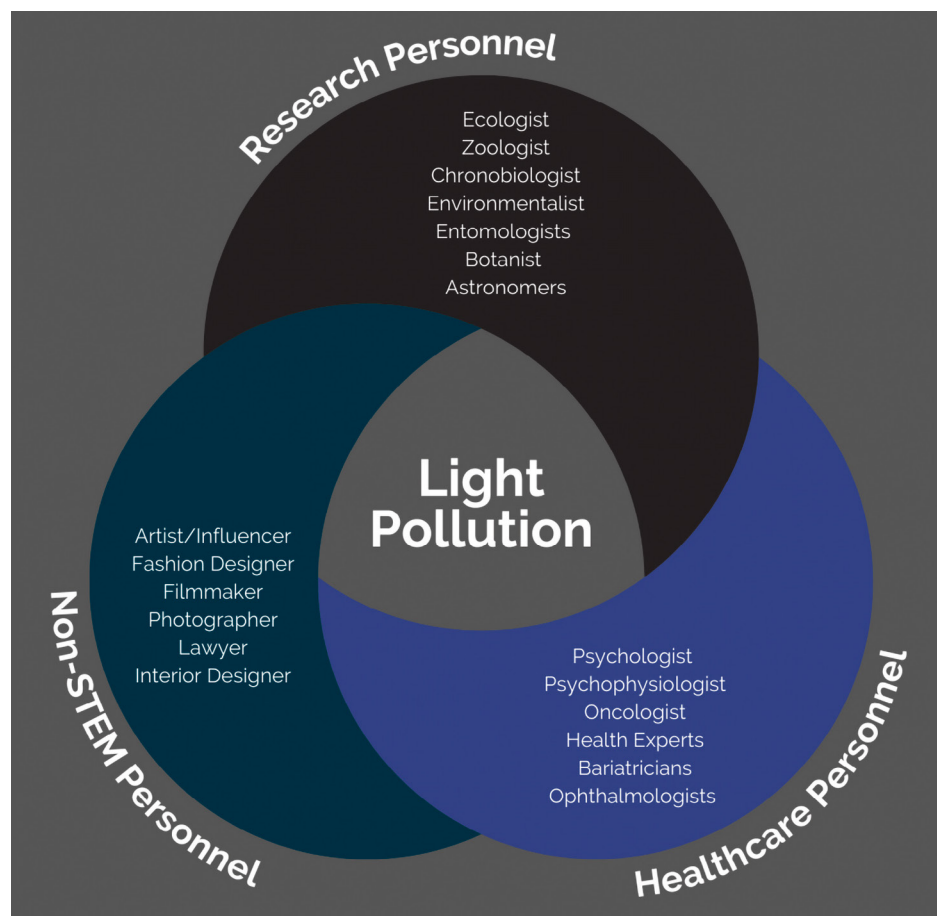


Figure 2: A Venn diagram showing the intersectionality of light pollution, particularly between research, non-STEM and healthcare personnel.

practical considerations. The authors advocate for interdisciplinary collaborations encompassing objective facts, existing practices, and core values to effectively address light pollution. Through this comprehensive approach, collaborative ideas are posited to generate substantive outcomes.

Interdisciplinary dialogues: A catalyst for informed science communication

Interdisciplinary collaboration is a pivotal mechanism for bridging the divide between scientific research and its practical application, as described in *Brownell et al. (2013)*. It facilitates communication between non-scientific stakeholders and science researchers and institutions. Concurrently, collaboration serves as a conduit for the reciprocal exchange of knowledge and resources, thereby optimising the efficacy of public engagement with science (e.g., *Stockmayer & Rennie, 2017*).

Diverse strategies may be employed to cultivate and promote collaborative initiatives. These include establishing dialogue and knowledge exchange platforms, including fora, workshops, or conferences designed to accommodate various perspectives. Furthermore, the inception of joint projects or programs uniting scientists and nonscientists to pursue shared objectives offers a tangible means of fostering collaboration.

Nevertheless, the efficacy of collaborative endeavours is contingent upon the mutual commitment of both scientific and non-scientific stakeholders to engage in active listening and maintain respect for each other's areas of expertise (e.g., *Yeatman, 1996*). A culture of open communication and receptivity to constructive feedback is imperative to ensure the effectiveness of collaborative undertakings. There is a need for reconsideration and enhanced collaboration in non-STEM disciplines to address societal challenges effectively (e.g., *Uddin et al., 2021*).

Dark Sky Superhero: A collaborative journey toward dark sky advocacy

This study explores a pioneering initiative in dark sky preservation by introducing the "Light Pollution Fighter", a superhero character tailored to address the prevalent

issue of light pollution. Motivated by the absence of superheroes dedicated to environmental causes, we present the origins and impact of the Light Pollution Fighter character and its associated costume. Harnessing the influential role of superheroes in shaping children's behaviour, our endeavour seeks to effectively raise awareness and instigate discussions on light pollution in an engaging and accessible manner. The conceptualisation of the Light Pollution Fighter is rooted in personal experiences: growing up as a child in Karachi, the author encountered hindrances to his astronomical pursuits due to light pollution.

Implemented with an environmentally sustainable ethos, the Light Pollution Fighter costume was meticulously fashioned from repurposed waste materials, including headphones, a smartphone, wires, headsets, car seat covers, toys, and scrap metal. Our primary objective was to convey the urgency of dark sky preservation through a creative and impactful medium, surpassing conventional modes of astronomy outreach such as public lectures or school visits. The success of this initiative relied on fruitful collaborations with visual artists and costume designers, emphasising the optimisation of individual strengths, realistic goal-setting, and adept utilisation of collaborative tools within the realms of art and social media.

This work demonstrates the imperative of diverse strategies in dark sky advocacy, encompassing educational initiatives, emotional resonance, and advocacy for legislative backing. Our innovative approach utilises art as a dynamic conduit for raising awareness, employing costumes to evoke public curiosity and initiate educational discussions (e.g., *Parks & White, 2021*). As a tangible outcome of our efforts, we unveiled the Light Pollution Fighter costume, symbolising our commitment to creatively addressing the challenges of light pollution. This contributes to the evolving discourse on inventive methodologies in environmental advocacy, highlighting the potency of artistic collaboration in fostering public engagement with critical issues.

Our distinctive costume (Figure 3) incorporates a smartphone device adept at converting the auditory signals produced by the Light Pollution Fighter into light signals. The costume is designed to activate the phone's light in response to the Light Pollution Fighter's speech, a feature strategically employed to highlight the contemporary reality that communication methods are increasingly mediated through light (e.g., *Rose, 2014*). Thus, the costume serves as a tool to amplify awareness regarding the pervasive effects of light pollution in our modern society.

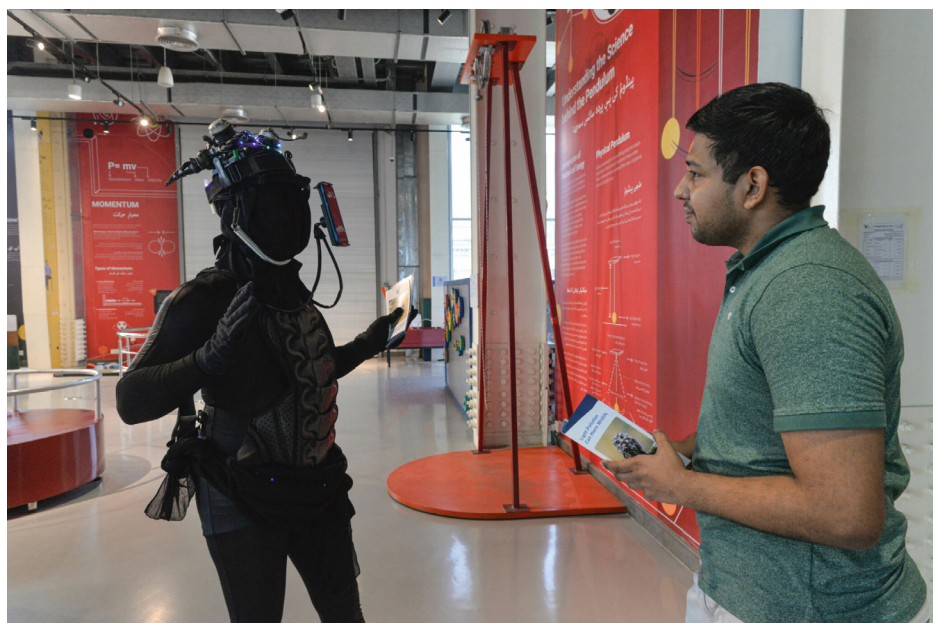


Figure 3: The Light Pollution Fighter discusses light pollution with a member of the public at an event at the TDF Magnificience Centre-Karachi Pakistan. Image Credit: TDF Magnificience Centre – Karachi, Pakistan

Our collaborative approach, specifically partnering with professionals beyond STEM fields – notably visual artists and costume designers – has proven to be a fruitful strategy for engaging a diverse audience. This innovative methodology enables us to present our research findings in a captivating, interactive, and easily comprehensible manner. Simultaneously, it represents the need to safeguard natural darkness. This interdisciplinary collaboration showcases the potential for non-traditional partnerships to enhance public engagement and understanding of complex scientific issues.

Unveiling the Dark Sky Defender: Bridging art and science to combat light pollution

The outcome of an interdisciplinary collaboration between artists and scientists, and based on the real-life Light Pollution Fighter, the Dark Sky Defender, shown in Figure 4, is a 3D animation marking a significant fusion of art and science to communicate the harmful effects of light pollution. The creation of this digital character stemmed from the recognition of the urgent need to raise awareness about light pollution and its detrimental effects on the environment and human health. The character symbolises the ongoing battle against light pollution, embodying the mission to protect natural darkness and

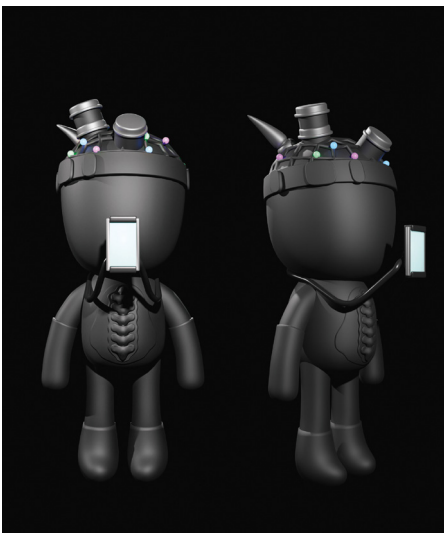


Figure 4: 3D Animated Character of Dark Sky Defender. Image Credit: Julia S. Champion

promote sustainable lighting practices. This initiative was driven by a desire to engage a wider audience, especially children and young adults, in understanding the significance of preserving dark skies and reducing artificial light at night.

This collaborative effort aims to leverage the aesthetic appeal of digital art alongside scientific knowledge, utilising digital storytelling to enhance public understanding and inspire action. The Dark Sky Defender character is an effective conduit, offering relatability and engagement to connect with audiences, exemplifying the impactful integration of diverse fields for innovative solutions to complex issues and promoting a more sustainable future.

The collaboration of artists and scientists who created the Dark Sky Defender 3D animation highlights promising avenues for future outreach and engagement strategies, including digital storytelling techniques to engage the public further (e.g., *Niemi & Multisilta, 2016*). Moving forward, we plan to expand the reach and impact of the digital character initiative through various channels. This includes developing digital content such as short videos, animations, and online campaigns featuring the character to reach a broader audience via social media platforms and educational websites. We aim to build collaborations with schools, environmental organisations, and local authorities to integrate light pollution awareness into curricula, community programs, and policy discussions.

When created, this new content will incorporate the Dark Sky Defender character in diverse ways, such as illustrating the detrimental effects of light pollution on wildlife or emphasising the economic benefits of reducing light pollution. Leveraging the character as a relatable and engaging persona, we aim to capture viewers' attention and have a lasting impact on their comprehension of the issue.

Collaborative storytelling with Luke Kornis

The author's collaboration with Luke Kornis is an innovative approach to raising awareness about environmental issues like light pollution while leveraging the influence of digital media and popular culture.

In 2021, the author collaborated with YouTube influencer Luke Kornis (*Kornis, 2021*) to shed light on the issue of light pollution and advocate for dark sky preservation in Pakistan. The project aimed to showcase Pakistan's unique landscapes and cultures through a travelogue, offering a fresh perspective on the nation. The collaborative effort included a journey from Karachi, Pakistan's largest city, located on the Arabian Sea coast in the South, to Hunza, a mountainous region in the North bordering China.

Figure 5 shows a light pollution map of Pakistan, with areas with high light pollution in white and areas with low light pollution in black.

The data for this light pollution map of Pakistan was obtained from the Visible Infrared Imaging Radiometer Suite (VIIRS-2021)-Day Night Band (DNB) with a spatial resolution of 15 arcseconds. The map incorporates data from twelve tiles (*Stare, 2022*) that were mosaicked and clipped to the country's border. The journey from Karachi to the Northern areas of Pakistan, as documented through the collaborative effort with Luke Kornis, is symbolically represented as a travel marker on the light pollution map of Pakistan, showcasing the expedition's geographic scope and thematic alignment with dark sky preservation.

The collaboration heightened awareness about the pressing need for dark sky protection, delineating the detrimental impacts of light pollution on the region's natural wonders. For example, Luke Kornis's YouTube channel boasts 2.36 million subscribers at the time of writing, which likely played a substantial role in the video's extensive reach (16.9 million impressions by 2022). In addition, Kornis's viewers are typically young people from the United States of America who may be predisposed to engaging in this kind of content.

The collaborative endeavour with Luke Kornis represents a positive and insightful experience. It provides a platform to disseminate knowledge on light pollution and its consequences in a compelling and imaginative manner. The outcomes reveal the potential of collaboration and storytelling as potent tools for raising awareness and fostering understanding of significant issues.

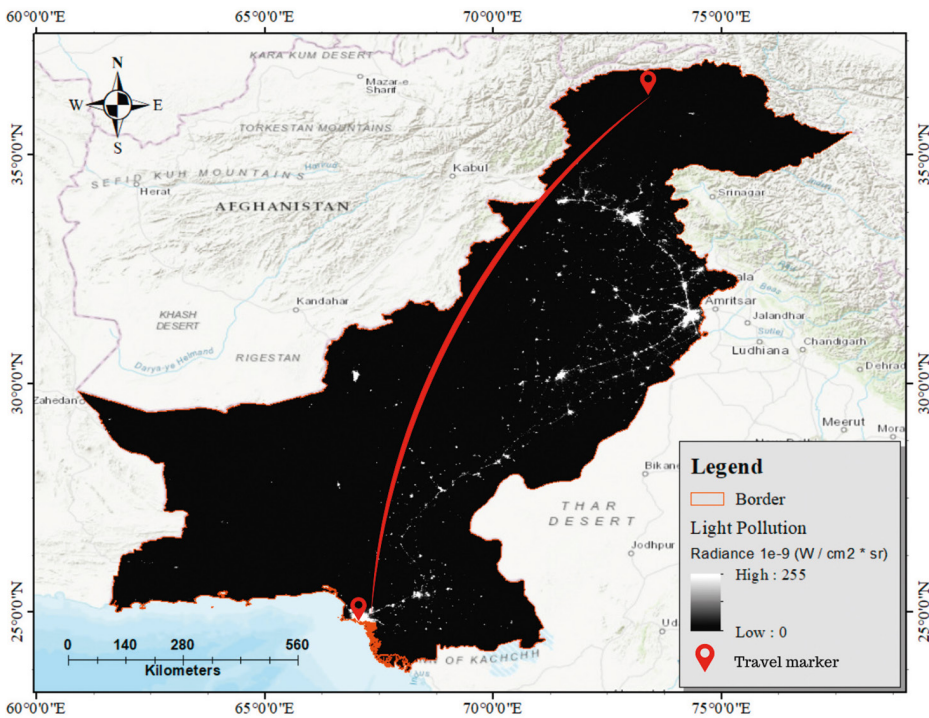


Figure 5: Light pollution map of Pakistan. The red line demonstrates the journey from Karachi to Northern Pakistan. Image Credit: Muhammad Aly Gajani

Collaborative horizons: Expanding public engagement on light pollution

Figure 6 visually represents various collaborative initiatives integrating art and science to address light pollution. The figure showcases three specific collaborations: an artist-astronomer collaboration, a musician-environmental scientist collaboration, and a photographer-community engagement collaboration. Each collaboration is designed to engage different audiences and convey the impacts of light pollution through creative and innovative means.

Artist and Astronomer Collaboration

An artist and astronomer can collaborate to create public art installations, such as an interactive light sculpture, raising awareness of light pollution's impact on observational astronomy (e.g., *Impey & Jasensky, 2018*).

Musician and Environmental Scientist Collaboration

A musician and an environmental scientist can collaborate to produce a music video highlighting the effects of light pollution on nocturnal animals

and their habitats, juxtaposing natural habitats with images of urban lighting (e.g., *MacDonald & Miell, 2000*).

Photographer and Community Engagement Collaboration

A photographer and a community group can collaborate to organise a public photography exhibition showcasing the beauty of the night sky and the significance of dark sky preservation. The exhibition could also include talks and workshops on astrophotography and the effects of light pollution (e.g., *Moore & Hatcher, 2019*).

Interdisciplinary collaborations that address complex environmental issues like light pollution benefit from several best practices that foster effective teamwork and meaningful outcomes. Mutual respect and understanding between artists and scientists are foundational for success in such collaborations (e.g., *Nowotny et al., 2003*). This involves appreciating each other's expertise, perspectives, and contributions, which can be achieved through open and transparent communication throughout the collaboration process (e.g., *Casado-Aranda et al., 2023*).

Furthermore, establishing clearly defined goals for the outreach project is crucial. These goals should align with the intended impact – in the case of this study, on public awareness and understanding of light

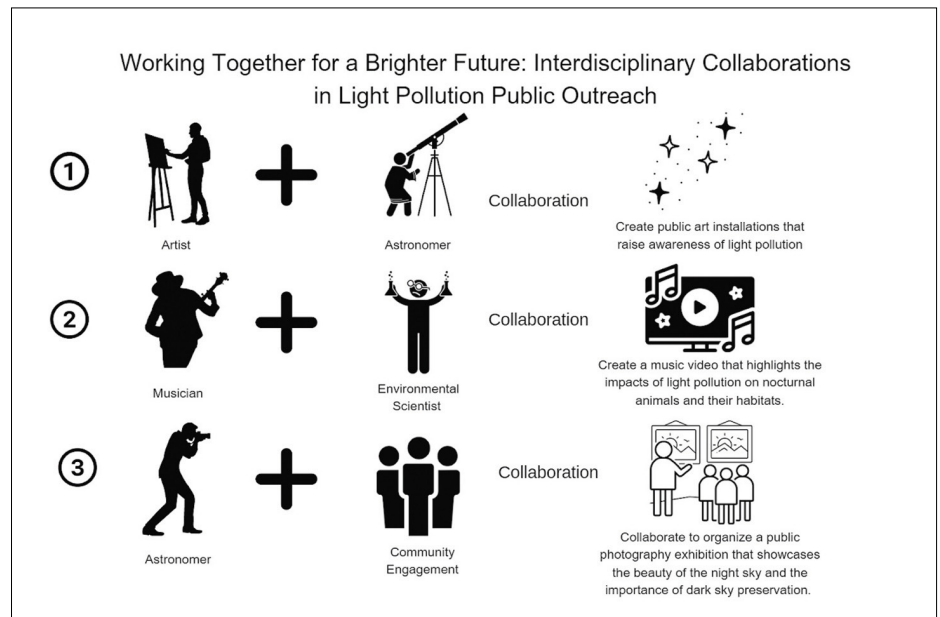


Figure 6: Interdisciplinary collaborations can be used to address light pollution, public outreach, and community engagement through artist-astronomer, musician-environmental scientist, and astronomer-community engagement collaborations.

pollution – ensuring that the artistic expression and scientific message are harmoniously integrated. A shared vision among collaborators regarding the project's objectives and desired outcomes is also essential (e.g., *de Ruiter et al., 2024, p. 202*). This shared vision serves as a driving force that motivates and guides collaborative efforts, leading to a cohesive and impactful final product. Additionally, leveraging each collaborator's strengths is paramount. Scientists can provide accurate and relevant factual information about light pollution, while artists can utilise their creativity and artistic skills to translate this information into engaging and accessible formats for diverse audiences (e.g., *Hicks et al., 2010*). By capitalising on these strengths and working collaboratively, interdisciplinary teams can create innovative and effective public engagement and advocacy strategies in environmental conservation.

The collaboration between artists and scientists in crafting the physical Light Pollution Fighter and the animated Dark Sky Defender is a significant advancement in integrating art and science to raise awareness about complex environmental issues like light pollution. Through sustained collaboration and ongoing innovation, the potential for utilising digital mediums to engage and inspire the public towards a more sustainable future remains substantial.

In the face of complex challenges requiring scientific solutions, ensuring a robust public understanding of science is more critical than ever. Interdisciplinary public engagement with science is vital to breaking down barriers between disciplines and enhancing communication. Collaborative efforts provide the public with essential information for making informed decisions about pressing issues like light pollution. Through our collaborative storytelling efforts on Luke Korn's channel, we have reached millions with the message of dark sky preservation and the impacts of light pollution. Ultimately, the night sky is not just for scientists but for us all.

Acknowledgements:

The author would like to extend his sincere gratitude to Luke Korn for his invaluable contribution to raising public awareness about light pollution through his compelling video storytelling on his YouTube Channel.

Korn's artistic talent has been instrumental in making this project possible, and I am profoundly thankful for his dedicated efforts.

Furthermore, the author would like to extend his profound gratitude to Ayesha Mubarak Ali for her steadfast support and acknowledgement of the crucial role played by interdisciplinary ideas in collaboration with the scientific community. Her active engagement in incorporating art into this project has not only expanded its accessibility but has also facilitated a broader understanding among a diverse audience, including non-experts, regarding the importance of preserving the dark sky from artificial lights at night. Muhammad Ali Gajani, thank you for your invaluable contribution to creating the maps used in this article using the ArcGIS tool, enhancing the visual representation of our research on light pollution and public engagement efforts.

The author also thanks Julia S. Champion for her significant contributions to our ongoing collaborative endeavours. Her Dark Sky Defender character has opened new avenues for us to delve into digital storytelling, amplifying the impact of light pollution awareness. Her 3D animation digital artwork has extended the reach of our project and brought a new dimension to our collective efforts. The author appreciates her unwavering dedication and commitment to advancing the cause of light pollution awareness.

References:

- Brownell, S., Price, J. V., & Steinman, L. (2013, December 9). Science communication to the general public: Why we need to teach undergraduate and graduate students this skill as part of their formal scientific training. *Journal of Undergraduate Neuroscience Education* 12(1), E6–E10. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3852879/>
- Butt, M. J. (2012). Estimation of light pollution using satellite remote sensing and geographic information system techniques. *GIScience & Remote Sensing*, 49(4), 609–621. <https://doi.org/10.2747/1548-1603.49.4.609>
- Casado-Aranda, L. A., Sánchez-Fernández, J., & Ibáñez-Zapata, J. Á. (2023). Evaluating communication effectiveness through eye tracking: Benefits, state of the art, and unresolved questions. *International Journal of Business Communication*, 60(1), 24–61. <https://doi.org/10.1177/2329488419893746>
- de Ruiter, N., Wittingslow, R., & Chiu, R. (2024). *Strange bedfellows: An experiment in student-directed interdisciplinary research*. University of Groningen Press. <https://doi.org/10.21827/6399d913c9fa9>
- Falchi, F., Cinzano, P., Duriscoe, D., Kyba, C. C. M., Elvidge, C. D., Baugh, K., Portnov, B. A., Rybnikova, N. A., & Furgoni, R. (2016). The new world atlas of artificial night sky brightness. *Science Advances*, 2(6). <https://doi.org/10.1126/sciadv.1600377>
- Gauntlett, D. (2007). *Creative explorations: New approaches to identities and audiences* (1st ed.). Routledge. <https://doi.org/10.4324/9780203961407>
- Hicks, C. C., Fitzsimmons, C., & Polunin, N. V. (2010). Interdisciplinarity in the environmental sciences: Barriers and frontiers. *Environmental Conservation*, 37(4), 464–477. <https://doi.org/10.1017/S0376892910000822>
- Hölker, F., Moss, T., Griefahn, B., Kloas, W., Voigt, C. C., Henckel, D., Hänel, A., Kappeler, P. M., Völker, S., Schwope, A., Franke, S., Uhrlandt, D., Fischer, J., Klenke, R., Wolter, C., & Tockner, K. (2010). The dark side of light: A transdisciplinary research agenda for light pollution policy. *Ecology and Society*, 15(4). <http://www.ecologyandsociety.org/vol15/iss4/art13/>
- Impey, C., & Jasensky, D. (2018). Visualizing the universe: The intersection of art and astronomy. *Mediterranean Archaeology and Archaeometry*, 18(4), 307–318. <https://doi.org/10.5281/zenodo.1477984>
- Korn, L. (2021, September 26). *My journey through Pakistan* [Video]. YouTube. <https://youtu.be/Yuen7pF5C1w>
- Lasker, R. D., & Weiss, E. S. (2003). Broadening participation in community problem solving: A multidisciplinary model to support collaborative practice and research. *Journal of Urban Health*, 80, 14–47. <https://doi.org/10.1093/jurban/jtg014>
- MacDonald, R., & Miell, D. (2000). Creativity and music education: The impact of social variables. *International Journal of Music Education*, 05-36(1), 58–68. <https://doi.org/10.1177/025576140003600107>
- MacLeod, M. (2018). What makes interdisciplinarity difficult? Some consequences of domain specificity in interdisciplinary practice. *Synthese*, 195(2), 697–720. <https://link.springer.com/article/10.1007/s11229-016-1236-4>
- Moore, J. E., & Hatcher, J. A. (2018). Disrupting traditional news routines through community engagement: Analysis of the One River, Many Stories media collaboration project. *Journalism Studies*, 20(5), 749–764. <https://doi.org/10.1080/1461670X.2017.1423238>

- Morand, S., & Lajaunie, C. (2019). Linking biodiversity with health and well-being: Consequences of scientific pluralism for ethics, values and responsibilities. *Asian Bioethics Review*, 11(2), 153–168. <https://doi.org/10.1007/s41649-019-00076-4>
- Nisar, H., Sarwar, F., Shirazi, S. A., Amjad, D., & Aslam, R. W. (2022). Assessment and Monitoring of VIIRS-DNB and SQML-L light Pollution in Lahore-Pakistan. *International Journal of Innovations in Science and Technology*, 4(1), 94–109. <https://doi.org/10.33411/ijist/2022040107>
- Nisbet, M. C. (2009). Communicating climate change: Why frames matter for public engagement. *Environment: Science and Policy for Sustainable Development*, 51(2), 12–23. <https://doi.org/10.3200/ENVT.51.2.12-23>
- Niemi, H., & Multisilta, J. (2016). Digital storytelling promoting twenty-first-century skills and student engagement. *Technology, Pedagogy and Education*, 25(4), 451–468. <https://doi.org/10.1080/1475939x.2015.1074610>
- Nowotny, H., Scott, P., & Gibbons, M. (2003). Introduction: 'Mode 2' revisited: The new production of knowledge. *Minerva*, 41(3), 179–194. <https://www.jstor.org/stable/41821245>
- Offe, C. (2019). New social movements: Challenging the boundaries of institutional politics (1985). In *Institutionen, Normen, Bürgertugenden. Ausgewählte Schriften von Claus Offe* (Vol. 3). Springer VS, Wiesbaden. https://doi.org/10.1007/978-3-658-22261-1_12
- Owen, R., Stilgoe, J., Macnaghten, P., Gorman, M., Fisher, E., & Guston, D. (2013). In R. Owen, J. Bessant, & M. Heintz (Eds.), *Responsible Innovation: Managing the Responsible Emergence of Science and Innovation in Society* (pp. 27–50). Wiley. <https://doi.org/10.1002/9781118551424.ch2>
- Pace, M. L., Hampton, S. E., Limburg, K. E., Bennett, E. M., Cook, E. M., Davis, A. E., Grove, J. M., Kaneshiro, K. Y., LaDeau, S. L., Likens, G. E., McKnight, D. M., Richardson, D. C., & Strayer, D. L. (2010). Communicating with the public: Opportunities and rewards for individual ecologists. *Frontiers in Ecology and the Environment*, 8(6), 292–298. <https://doi.org/10.1890/090168>
- Parks, P., & White, L. (2021). Foregrounding backgrounds: How scientists conceive art to express the invisible. *Science Communication*, 43(4), 435–459. <https://doi.org/10.1177/10755470211011166>
- Pérez Vega, C., Zielinska-Dabkowska, K. M., & Hölker, F. (2021). Urban lighting research transdisciplinary framework — A collaborative process with lighting professionals. *International Journal of Environmental Research and Public Health*, 18(2), 624. <https://doi.org/10.3390/ijerph18020624>
- Rose, G. (2014). On the Relation between 'Visual Research Methods' and Contemporary Visual Culture. *The Sociological Review*, 62(1), 24–46. <https://doi.org/10.1111/1467-954x.12109>
- Sleigh, C., & Craske, S. (2017). Art and science in the UK: A brief history and critical reflection. *Interdisciplinary Science Reviews*, 42(4), 313–330. <https://doi.org/10.1080/03080188.2017.1381223>
- Stare, J. (2022). VIIRS Country Statistics. https://www.lightpollutionmap.info/LP_Stats/
- Stilgoe, J., Lock, S. J., & Wilsdon, J. (2014). Why should we promote public engagement with science?. *Public Understanding of Science*, 23(1), 4–15. <https://doi.org/10.1177/0963662513518154>
- Stocklmayer, S.M., Rennie, L.J. (2017). The attributes of informal science education: A science communication perspective. In P. G. Patrick (Ed.), *Preparing Informal Science Educators*. Springer, Cham. https://doi.org/10.1007/978-3-319-50398-1_26
- Uddin, S., Imam, T., & Mozumdar, M. (2021). Research interdisciplinarity: STEM versus non-STEM. *Scientometrics*, 126(1), 603–618. <https://doi.org/10.1007/s11192-020-03750-9>
- Wynne, B. (2006). Public engagement as a means of restoring public trust in science—hitting the notes, but missing the music?. *Public Health Genomics*, 9(3), 211–220. <https://doi.org/10.1159/000092659>
- Yeatman, A. (1996). The roles of scientific and non-scientific types of knowledge in the improvement of practice. *Australian Journal of Education*, 40(3), 284–301. <https://doi.org/10.1177/000494419604000306>
- Zia, H., Khan, T., Fatima, H. S., Khurram, M., Harris, N. R., & Khalil, A. (2022). *Impacts of urbanization on green spaces of the densely populated city of Karachi, Pakistan – An analysis of 8 years of data for estimating land cover changes*. Research Square. <https://doi.org/10.21203/rs.3.rs-1934043/v1>

Biography

Muhammad Rayan Khan is the Director/CEO of the Cosmic Tribe, IAU Dark Skies Ambassador, IAU National Astronomy Education Coordinator – NAEC OAE, International Dark Sky Association IDA Delegate/Advocate, IAAA – International Association of Astronomical Artists – Director of STEAM Outreach (DoSO), and Young Persons Committee Head of the Royal Aeronautical Society Pakistan Division. Khan is known by the name of Light Pollution Fighter in Pakistan. He actively promotes dark-sky protection through interdisciplinary collaborations.