

Marine Ecology Enhancement Fund (MEEF) Completion Report

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Project title

3D Technology-Enhanced Aquatic Conservation Hub (3D TEACH): an artificial reef initiative for ecological restoration and conservation education

Executive summary

The 3D Technology-Enhanced Aquatic Conservation Hub (3D TEACH) is an innovative initiative that integrates micro-computed tomography (micro-CT), 3D printing, and extended reality, to advance marine ecological restoration and conservation education. Supported by the Marine Ecology Enhancement Fund, the project's primary objective is to leverage advanced technologies to restore deteriorated marine habitats while providing a multifaceted educational framework for younger generations. On the restoration front, the project has successfully designed and manufactured bespoke 3D-printed artificial reefs. These structures feature biomimetic coral topography to replicate the rugosity of natural reef systems, providing essential niches for diverse marine taxa and enhancing local biodiversity. A significant technical innovation is the integration of detachable "plug units" designed for coral larval settlement. These units support a sexual reproduction-based approach to restoration, as they can be detached and moved to laboratories for ex-situ breeding, ensuring the genetic diversity and long-term resilience of local coral populations. The educational component of 3D TEACH achieved significant reach, engaging over 900 students across primary, secondary and tertiary sectors through a curriculum that blended theory with cutting-edge technological demonstrations. Students participated in immersive workshops using the Hybrid Immersive Virtual Environment (HiVE), a pioneering 3D simulation platform at The Hong Kong Polytechnic University that allowed them to explore 360-degree virtual coral reefs. To further bridge abstract biological concepts with physical reality, the project utilised micro-CT and 3D printing to create high-resolution, magnified models of coral skeletons. These tangible models provided a hands-on experience, allowing students to examine the intricate morphology of different coral species firsthand. To complement laboratory and virtual learning, the initiative organised experiential excursions to the WWF Hoi Ha Marine Life Centre and Hoi Ha Wan Marine Park. Participants observed 3D-printed reefs strategically deployed in the Marine Park via glass-bottom boats, witnessing the real-world application of the technologies they studied. This multifaceted approach proved highly effective in fostering scientific literacy and environmental stewardship. By integrating interactive discussions and cross-disciplinary perspectives, the project inspired active engagement and a deeper appreciation for the ecological vulnerability of the marine environment.

Brief description of the project

As shown literally by the acronym 3D TEACH, our goal is to utilise 3D technology for educational purposes in the field of marine conservation, building upon our expertise in ecological restoration. By leveraging 3D printing capabilities, we fabricate artificial reefs to restore the deteriorated ecological habitats in Hong Kong. The advantages of using 3D-printed artificial reefs include easy handling and the flexibility to be customised to any size and shape, creating structural complexity that can enhance local biodiversity. The scientific insights and practical knowledge gained from this restoration endeavour provide important teaching materials for our conservation education activities, primarily targeting young generations in three aspects: Firstly, our 3D-printed artificial reefs have been strategically deployed within the Hoi Ha Wan Marine Park and are accessible for tours by schools and the public aboard a glass-bottom boat. This provides a unique opportunity for visitors to witness firsthand the ecosystem developed on the 3D-printed reef structures. Secondly, we employ micro-computed tomography (micro-CT) and 3D printing technologies to create high-resolution 3D models of coral skeletons. These models are utilised in outreach activities, allowing students and the public to closely observe the intricate details of different coral species. This hands-on experience enhances their appreciation of marine biodiversity. Thirdly, we incorporate an advanced extended reality system, known as the Hybrid Immersive Virtual Environment (HiVE), to provide an engaging learning experience to explore a 360° virtual underwater world. This visually appealing activity deepens participants' understanding of marine ecology and ignites their interest in marine conservation. Overall, the implementation of 3D printing, micro-CT and HiVE technologies in the 3D TEACH initiative serves as a compelling demonstration of how advanced technologies can be applied to marine ecological restoration and conservation education.

Results/descriptions on the completed activities

The project's educational framework is built upon a multifaceted approach, integrating marine conservation workshops with cutting-edge technological demonstrations. Central to this initiative are the guided tours of the Hybrid Immersive Virtual Environment, a pioneering 3D simulation platform established by The Hong Kong Polytechnic University. By leveraging this sophisticated facility, we provided participants with a highly engaging and immersive learning experience focused on marine ecology and the urgent necessity of environmental stewardship.

To date, a comprehensive series of community educational activities has successfully engaged over 1,200 participants from diverse age groups and sectors (Table 1). The curriculum for these sessions was carefully curated to include theoretical foundations regarding the mechanics of artificial reefs and the complex dynamics of coral reef ecology. These sessions were further enhanced by technical site visits to the University Research Facility in 3D Printing (Fig. 1). Through the Hybrid Immersive Virtual Environment system, students were afforded the unique opportunity to navigate 360-degree virtual coral reefs, allowing for an in-depth exploration of the ecological significance of biodiversity within a controlled, high-fidelity environment designed to deepen their understanding of contemporary conservation issues (Fig. 2).

Table 1: Summary of community education activities organised.

Dates	No. of Participants	Participating Organisation	Participants	Activities
3 Oct 2024	20	The Harbour School	Grade 8–9 students	The students visited PolyU, where they engaged in a series of educational activities. These included a

				workshop on coral ecology and biodiversity, an immersive virtual reality experience exploring a 360° coral reef through the Hybrid Immersive Virtual Environment (HiVE), a tour of the 3D printing research facilities, and a showcase demonstrating 3D-printed artificial reefs and coral models.
16 Oct 2024	30	PolyU	BSc students	The students attended a seminar on coral ecology and the associated impacts of climate change. They also had the opportunity to experience a 360° virtual coral reef using HiVE.
24 Oct 2024	288	Wah Yan College Hong Kong	Form 1–3 students	This was a school outreach programme that provided a seminar on coral ecology and the application of artificial reefs in coral restoration, with case studies from Hong Kong.
6 Nov 2024	23	SALEM-Immanuel Lutheran College	Form 3–4 students	This was a school outreach programme that provided a seminar on coral ecology and the application of artificial reefs in coral restoration, with case studies from Hong Kong.
21 Nov 2024	300	HKWMA Chu Shek Lun Secondary School	Form 4–6 students	This was a school outreach programme that provided a seminar on coral ecology and the application of artificial reefs in coral restoration, with case studies from Hong Kong.
24 Nov 2024	20	PolyU	BSc students	This was a guided tour to Hoi Ha Wan Marine Park, where the students joined a workshop on coral biology and marine ecological techniques, including seawater sampling and plankton counts. They also boarded a glass-bottom boat to observe native coral communities and the artificial reefs deployed within the Marine Park.
13 Feb 2025	56	PolyU	MSc students	The students attended a seminar on coral ecology and the associated impacts of climate change. They also had the opportunity to experience a 360° virtual coral reef using HiVE.
27 Feb–4 Mar 2025	431	St Catherine's International Kindergarten	Level K3 students	The children, accompanied by their teachers, visited PolyU and participated in a variety of educational activities. These comprised a workshop on coral biology and marine life, an immersive virtual reality exploration of a 360° coral reef using HiVE, a tour of the child-friendly facilities at the 3D printing research centre, and a showcase featuring 3D-printed coral models and engaging 3D-printed toys aiming to fostering their interest in technology and marine conservation.
6 Apr 2025	40	PolyU FSN5016	MSc students	This was a guided tour to Hoi Ha Wan Marine Park, where the students joined a workshop on coral biology, the impacts of human activities, and coral conservation. They also boarded a glass-bottom boat to observe native coral communities and the artificial reefs deployed within the Marine Park.
8–17 Apr 2025	46	Ngong Ping 360	Working professionals	The cable cars of Ngong Ping 360 run directly above the western waters of Hong Kong, which inspired us to invite the corporation to visit PolyU with the aim of raising staff awareness of marine conservation. The activities included a workshop on coral ecology and 3D printing technology, an immersive virtual reality experience exploring a 360° coral reef using HiVE, a tour of the 3D printing research facilities, and a showcase demonstrating 3D-printed artificial reefs and coral models.



Fig. 1: Technical site visits to the University Research Facility in 3D Printing at The Hong Kong Polytechnic University.



Fig. 2: Immersive learning experience using the Hybrid Immersive Virtual Environment system at The Hong Kong Polytechnic University.

A key pedagogical innovation within these activities involved the development of high-resolution, magnified 3D models of coral skeletons for educational purposes (Fig. 3). These models were meticulously generated using micro-computed tomography scanning in conjunction with advanced 3D printing technologies. By translating microscopic biological data into tangible, large-scale physical structures, we enabled students to examine the intricate and fascinating morphology of diverse coral species. This tactile engagement served to bridge the gap between abstract biological concepts and the physical reality of marine life, effectively fostering a deeper academic interest in marine biology.

To complement and contextualise these laboratory and virtual components, experiential learning excursions to the WWF Hoi Ha Marine Life Centre were organised (Fig. 4). A primary

highlight of these tours involved transporting participants via glass-bottom boat to observe the 3D-printed artificial reefs strategically deployed within the Hoi Ha Wan Marine Park. This excursion offered a memorable, non-invasive opportunity for students to explore the underwater world and observe Hong Kong's indigenous stony corals firsthand. By witnessing the practical application of their studies in a natural setting, students were able to cultivate a profound appreciation for the natural beauty and ecological vulnerability of the marine environment.

Although Project MEEF2024018 has now ended, we remain committed to organising similar educational activities for students and the community, making the best use of the 3DTEACH platform that was built and benefited from the project.

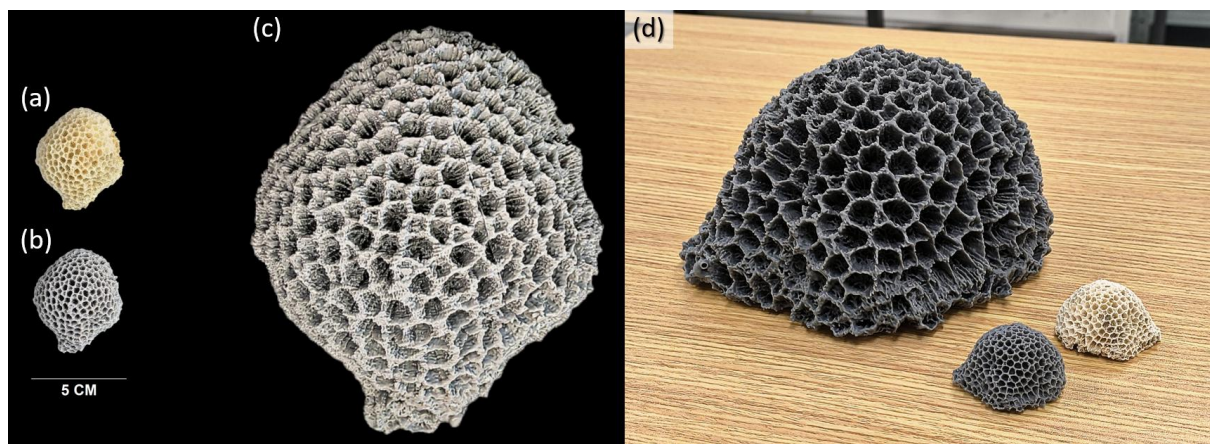


Fig. 3: (a) Original coral skeleton of *Leptastrea* sp.; (b) its real-scale 3D-printed model and (c) magnified-scale 3D-printed model; (d) the models on display, allowing students to touch and explore coral morphology through direct handling.

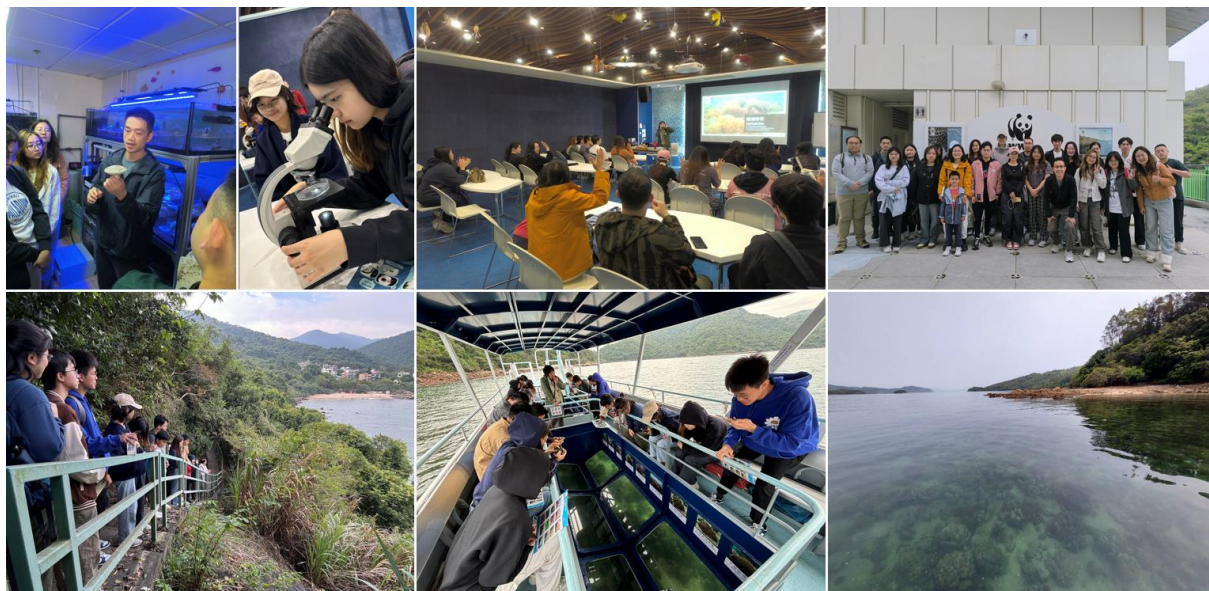


Fig. 4: Guided tours to the WWF Hoi Ha Marine Life Centre and the Hoi Ha Wan Marine Park.

Another objective of this project, designed to complement our educational outreach, was the fabrication and deployment of bespoke 3D-printed artificial reefs within Hong Kong's waters. These units were specifically engineered to facilitate the restoration of degraded marine habitats by providing structurally complex foundations for sessile organisms. The reef modules

feature biomimetic coral topography, a design intended to maximise ecological relevance and enhance the structural complexity (Fig. 5a). By replicating the rugosity of natural reef systems, these structures provide essential niches for diverse marine taxa. A significant innovation in this restoration framework is the integration of “plug units” specifically designed for coral larval settlement (Fig. 5b). These specialised units can be seamlessly detached and transported to a laboratory setting to act as recruitment surfaces during ex-situ artificial breeding cycles. By utilising these plugs for coral larval settlement, the project supports a sexual reproduction-based approach to restoration, which is vital for maintaining the genetic diversity and long-term resilience of local coral populations. This methodology ensures a sustainable and scalable source of coral colonies for active field transplantation.

All required artificial reefs have been manufactured, and all necessary preparations have been completed. However, formal approval for deployment within Hong Kong’s waters was granted by the Agriculture, Fisheries and Conservation Department in November 2025. As this authorisation was issued near the scheduled conclusion of the current project cycle, the physical deployment could not be executed within the original project duration. Notwithstanding the expiration of the formal project period, we remain committed to the execution of this restoration activity. The deployment will proceed as planned to fulfil our ecological objectives for the marine environment. In this regard, we have successfully deployed three artificial reefs in Yan Chau Tong Marine Park in July 2026. The reefs will be monitored quarterly, in October 2026, January 2027, April 2027, and July 2027. We are observing the settlement of marine life on the reefs and tracking coral growth in terms of surface area expansion. In addition, we are exploring the feasibility of using 3D scanning to reconstruct digital models of the reefs, which would enable quantitative growth estimates such as increase in volume. We wish to clarify that this continued work will be conducted using internal resources, and no additional funding will be sought from MEEF2024018 to complete this phase of the initiative.

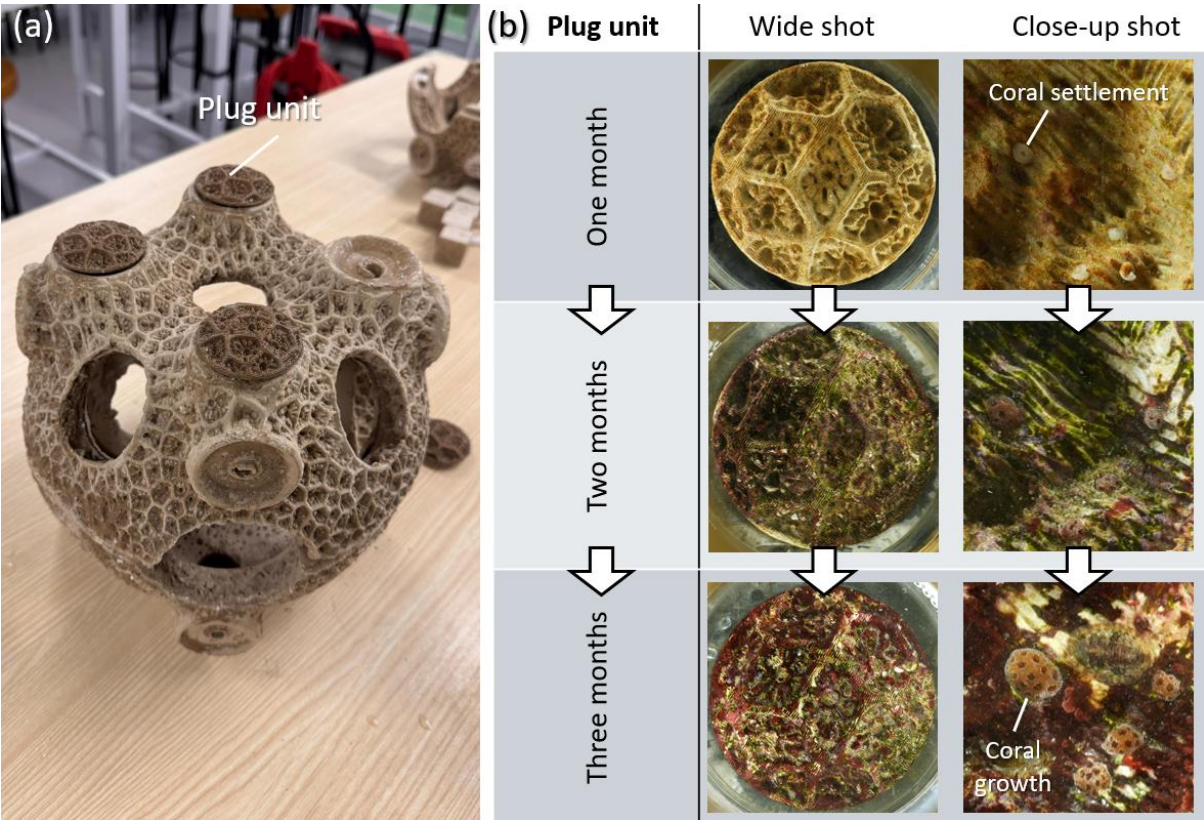


Fig. 5: (a) Artificial reef structure designed and manufactured by the study team, incorporating detachable plug units that can be easily transferred to the laboratory to serve as substrates for coral larval settlement; **(b)** time-series photographs illustrating the settlement of coral larvae and their subsequent growth over a three-month period on the plug units.

Completed activities against the proposed work schedule

All proposed tasks have been completed in accordance with the work schedule, with the exception of the deployment of the artificial reefs (Table 1). Formal approval for deployment within Hong Kong’s waters was granted in November 2025, close to the scheduled end of the current project cycle. As a result, this task could not be completed within the project period. Nevertheless, we remain committed to carrying out the deployment after the project’s conclusion, without seeking additional funding from MEEF2024018.

Table 1. Approved timetable (completed tasks in blue)

Ecological restoration and conservation education activities	Jul/ Aug 2024	Sep/ Oct 2024	Nov/ Dec 2024	Jan/ Feb 2025	Mar/ Apr 2025	May/ Jun 2025	Jul/ Aug 2025	Sep/ Oct 2025	Nov/ Dec 2025
Project kick-off, and administration									
Design and production of 3D-printed artificial reefs									
Deployment of the artificial reefs									
Tours to visit the Hoi Ha Wan Marine Park									
Outreach activities using the 3D coral models									
Tours to visit the Hybrid Immersive Virtual Environment at PolyU									
Project conclusion, and preparation of the completion report									

Evaluation of the project effectiveness

The project is advancing marine conservation awareness by integrating innovative fabrication, targeted education, and experiential learning. The manufacture of artificial reef units has been successfully achieved, demonstrating the project’s technical feasibility and commitment to ecological restoration. These units are designed to provide essential habitats, directly contributing to biodiversity enhancement and the recovery of degraded seabed environments. This work addresses a critical environmental challenge while showcasing the practical application of technology in marine restoration. From an educational perspective, the initiative has significantly broadened its reach and effectiveness. Workshops introduced core concepts such as artificial reefs and the application of 3D printing for ecological purposes, while visits to the University Research Facility in 3D Printing bridged theory and practice, fostering deeper understanding among younger participants. The programme also employed the Hybrid Immersive Virtual Environment, enabling exploration of a virtual coral reef. This innovative session enhanced comprehension of marine ecosystems and their threats, using immersive technology to communicate complex conservation issues in a compelling and accessible manner.

To anchor this learning in real-world experience, field visits to the WWF Hoi Ha Marine Life Centre were organised, providing firsthand observation of local stony corals and reinforcing the imperative of marine protection. Beyond these activities, the project has demonstrated the

value of combining advanced technologies with traditional field-based learning. By integrating 3D printing, virtual reality, and direct ecological observation, it created a multifaceted and impactful programme that not only raised awareness but also inspired active engagement. Importantly, the educational design has been expanded to include interactive discussions, open-ended questioning, and cross-disciplinary perspectives, encouraging critical thinking and reflection among participants. The inclusion of diverse audiences, from schoolchildren to university students and community members, ensured that conservation messages were disseminated widely and adapted to different levels of understanding. This layered approach has increased the effectiveness of education by fostering curiosity, building scientific literacy, and cultivating a sense of stewardship for the marine environment. By combining advanced technologies, experiential learning, and inclusive outreach, the project has set a persuasive precedent for future interdisciplinary conservation initiatives, demonstrating how technical innovation can be harnessed to inspire and sustain environmental education.

Summary and way forward

The 3D TEACH project has successfully demonstrated how advanced technologies can be harnessed to advance both ecological restoration and conservation education. Through workshops, site visits, virtual simulations, and hands-on engagement with coral models, the initiative has reached students across multiple educational levels, fostering scientific literacy and environmental stewardship. The fabrication of bespoke artificial reef units, incorporating detachable plug systems for coral larval settlement, further highlights the project's innovative contribution to sustainable marine restoration. Looking ahead, the immediate priority is the deployment of the manufactured artificial reefs within Hong Kong's waters, following the formal granted approval. Although this task could not be completed within the original project cycle, the team remains committed to its execution using internal resources, without seeking additional funding from MEEF. The deployment of the reef structures is estimated to take place in July 2026, after which the reefs will undergo regular monitoring for 12 months. Beyond deployment, the project will continue to expand its educational reach by integrating reef monitoring outcomes into teaching materials, refining interactive learning modules, and strengthening collaborations with schools, NGOs, and community partners. This forward trajectory ensures that the ecological and educational impacts of 3D TEACH will be sustained, scaled, and embedded within Hong Kong's broader marine conservation framework.

Staff recruitment record and attendance record

Staff recruitment record and attendance record are not disclosed due to confidentiality reasons.

Financial statement of the project

Financial statement is not disclosed due to confidentiality reasons.

Declaration

I hereby irrevocably declare to the MEEF Management Committee and the Steering Committee of the relevant Funds including the Top-up Fund, that all the dataset and information included in the completion report has been properly referenced, and necessary authorisation has been obtained in respect of information owned by third parties.

Disclaimer

Any opinions, findings, conclusions or recommendations expressed in this report do not necessarily reflect the views of the Marine Ecology Enhancement Fund or the Trustee.



Signed by
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