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Empowering Citizen Scientists Through Virtual Marine Heritage with Epoxonomy©

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Abstract

Taxonomy is often undervalued, perceived merely as a descriptive science focused on identification, with limited career prospects. However, taxonomy plays a crucial role in conservation biology and informs policy decisions, adhering to ethical standards. This is particularly significant for Malaysia, a central biodiversity hotspot, where public awareness of marine biodiversity's value is lacking. Addressing this challenge involves educating the public on the importance of taxonomy and marine biodiversity for the sustainable management of natural heritage resources through citizen science. This paper introduces EpoXonomy©, a novel initiative designed to enhance engagement between marine experts, youth, and the public, emphasizing the significance of biological collections from the South China Sea Repository and Reference Center. EpoXonomy© utilizes a virtual exhibition format to achieve its goals, structured around three core learning outcomes (CLOs). These CLOs aim to bridge marine taxonomic discoveries, educational awareness, and online exhibitions through a collaborative effort involving trained academicians, curators, industrial experts, and undergraduate students. The project's primary objective is to inspire a younger generation to value their natural heritage by engaging trained taxonomists and curators and fostering a citizen science community. This community is nurtured through the training and empowerment of undergraduate students in marine biology. Additionally, EpoXonomy© seeks to provide avenues for public participation and stimulate early interest in scientific research, facilitating knowledge transfer and raising awareness in alignment with the themes and objectives of Sustainable Development Goal 14 (Life Below Water). In summary, EpoXonomy© represents a comprehensive approach to marine heritage awareness, knowledge dissemination, and readiness among citizen scientists, ultimately contributing to the long-term sustainability of marine biodiversity through informed public engagement and education.

Keywords: Taxonomy; EpoXonomy©, Conversation, Biological Collections, Educational Outreach, Youth Empowerment

1.0 INTRODUCTION

Taxonomy is a fundamental science that underpins the universal naming and classification of more than two million species worldwide, establishing an organized system of biodiversity classification that has persisted for centuries (Thomson et al., 2018). The pursuit of discovering, describing, and classifying the species of our planet is undeniably a grand scientific endeavor, and it should be recognized as a pioneering discipline that continues to integrate and expand upon new knowledge (Wilson, 2004; Wheeler et al., 2004). However, the value of this classification system is profoundly dependent on the reference of biological specimens housed in museums and repositories. These specimens provide essential physical evidence of the morphological and genetic characteristics used to define species, enabling taxonomists to accurately identify and describe new species and understand the relationships among different organisms.

1.1 Background

Museums and repositories hold vast collections of these specimens, accumulated over centuries of research and exploration, making them invaluable resources for scientific research and education. Without tangible specimens, the study of taxonomy would be confined to theoretical and speculative realms, rendering it incomplete and inaccurate (Engel et al., 2021). These collections, therefore, are crucial for illustrating and cataloging the diversity of life on Earth, particularly at a time when biodiversity loss is accelerating at an alarming rate. Despite their significance, the potential of these collections is often hindered by a shortage of trained taxonomists and limited public engagement.

1.2 Motivation for the Study

To fully realize the biological significance of these collections, innovation in taxonomy is essential. Such innovation would not only facilitate the identification and description of new species

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but also enhance public awareness and interest in the natural world. Citizen science emerges as a vital approach to bridge the gap between taxonomic discovery and public engagement, fostering education and outreach by trained experts. This necessity for innovation and public engagement has led to the conceptualization of EpoXonomy©. EpoXonomy© is a mobile exhibition that curates the taxonomy and biodiversity significance of museum specimen collections through artistic resin dioramas. The project name amalgamates "Epoxy" and "Taxonomy," symbolizing the fusion of scientific taxonomy with the art of epoxy resin.

1.3 Objective and Scope of the Study

EpoXonomy© aims to address the challenges of harnessing the biological significance of museum collections impeded by a lack of trained taxonomists and poor public engagement. By creating portable, artistic displays, the project seeks to raise awareness and engage the public, with a particular focus on ocean literacy. Aligned with the United Nations Sustainable Development Goal (SDG) 14: Life Below Water, this project is situated at the South China Sea Repository and Reference Centre (RRC) in Kuala Nerus, Terengganu, Malaysia. The RRC, which houses approximately 50,000 specimen lots predominantly of marine biodiversity, serves as an ideal subject area due to its wealth of information crucial for understanding broader issues such as climate change, ecological health, and biosecurity. The EpoXonomy© initiative aims to create student-centered learning on marine sustainability and awareness through RRC's collections and to foster a citizen science learning experience. By guiding and encouraging students to communicate marine biodiversity awareness and discuss solutions through exhibitions, the project endeavors to engage the public comprehensively across various age groups and demographics. During the Covid-19 pandemic, the project adapted to a virtual format, utilizing Facebook to host the exhibition during World Ocean Week in June 2021. Marine Biology undergraduate students, enrolled in the elective course MMB3314: Biological Classification for Marine Organisms, are taught practical taxonomic and curatorial skills, implementing EpoXonomy© as part of their coursework. This approach covers three course learning outcomes (CLOs), with theoretical skills assessed through lectures and laboratory sessions, and problem-solving skills evaluated through practical and exhibition case studies. The students further extend this knowledge to the public through a citizen science approach, sharing pre- and post-surveys of the EpoXonomy© project to enhance ocean awareness across diverse demographics.

This paper aims to explore the knowledge, awareness, and preparedness of citizen scientists regarding EpoXonomy©. The innovation is crucial to addressing the gap in public knowledge of marine diversity in Malaysian waters. Despite the irony that a significant portion of the Malaysian population has direct or indirect access to the ocean, most lack awareness of marine biodiversity's diversity and importance. By assessing and enhancing public knowledge through EpoXonomy©, the project seeks to foster a greater appreciation for marine resources and drive efforts towards their sustainable conservation.

2.0 LITERATURE REVIEW

2.1 The Challenges and Perception of Taxonomy in Modern Science

Taxonomy, the science of classifying and naming organisms, faces numerous hurdles in modern science. A common misconception is that taxonomy is an unnecessary and time-consuming discipline, with its significance often overlooked. Original taxonomic descriptions, synonymies, and revisions are foundational to biological studies, yet they are frequently under-cited in scientific literature (Werner, 2006). This undervaluation extends to the impact of taxonomic research, deterring many young scientists from pursuing this field. Prominent taxonomic journals have lower impact factors compared to those in evolutionary biology, further diminishing the perceived value of taxonomic work. Moreover, traditional taxonomic publications often focus narrowly on morphology, offering weakly tested species hypotheses. Incorporating additional data such as behavior, natural history, and molecular markers can enhance the impact and utility of taxonomic research (Hebert et al., 2003; Tautz et al., 2003; Hebert and Barrett, 2005; Gregory, 2006; Pons et al., 2006; Robins et al., 2006).

2.2 Importance of Biological Collections and Digitization Efforts

Biological collections housed in museums and academic institutions are invaluable for scientific research and education. These collections have significantly contributed to various fields, including environmental monitoring, systematics, and public understanding of biodiversity (Graham et al., 2004; Berendsohn and Seltmann, 2010). With approximately two billion specimens globally (Ariño, 2010), these collections contain extensive taxonomic, geographic, and temporal data. However, much of this information remains underutilized. Recent efforts have focused on digitizing these collections to enhance accessibility and integration into broader scientific databases. Initiatives like the National Science Foundation's Advancing Digitization of Biodiversity Collections (ADBC) and the Ocean Biogeographic Information System (OBIS) exemplify large-scale digitization projects that facilitate research on climate change, ecological health, and biodiversity conservation.

2.3 Engaging the Public in Taxonomy Through Citizen Science

Citizen science involves public participation in scientific research, often through data collection and processing. This approach has proven effective in enhancing public engagement and contributing valuable data to scientific studies. Platforms like Zooniverse, eBird, and iNaturalist enable citizen scientists to participate in diverse projects, including biological specimen transcription. Projects like Herbaria@home and the Atlas of Living Australia Biodiversity Volunteer Portal have successfully digitized thousands of specimens, making them accessible for research. In Malaysia, there is a need to cultivate a culture of citizen science, particularly in taxonomy and biodiversity. Implementing citizen science modules in educational settings can bridge the gap between scientific research and public

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awareness, fostering a greater appreciation for biodiversity and conservation efforts.

2.4 The South China Sea Repository and Reference Centre: Evolution and Functions

The South China Sea Repository and Reference Centre (RRC) has evolved significantly since its establishment as the Biodiversity Museum in 2004. Now housing over 50,000 specimen lots, including crucial "Type" materials, RRC serves as a major repository for marine biodiversity in Malaysia. The center adheres to global standards for the conservation and management of marine specimens, facilitating research and education worldwide. RRC's primary functions include preserving specimens, maintaining a comprehensive database, preparing collections for various uses, and fostering collaborations with other institutions. These efforts ensure that RRC remains a vital resource for understanding marine biodiversity, climate change impacts, and ecological health.

2.5 Development and Impact of MMB3314: Biological Classification of Marine Organisms

The elective course MMB3314, Biological Classification of Marine Organisms, addresses the need for increased ocean literacy and sustainable use of marine resources. Launched in 2019, the course integrates theoretical and practical aspects of marine taxonomy, utilizing RRC's extensive collections. Students gain hands-on experience in curatorial practices, enhancing their understanding of marine biodiversity and conservation. The course's structure, which includes lectures, laboratory sessions, and practical case studies, prepares students to contribute to scientific research and public outreach. By involving students as volunteers, MMB3314 not only supports their education but also aids in the maintenance and utilization of RRC's collections for broader scientific purposes.

2.6 Innovation in Taxonomy Outreach: The EpoXonomy© Initiative

EpoXonomy©, a portmanteau of "Epoxy" and "Taxonomy," represents an innovative approach to engaging the public with the science of taxonomy through art. This initiative curates taxonomic information and biological specimens within artistic epoxy resin dioramas, making the science accessible and visually appealing. EpoXonomy© aims to address the challenges of limited public engagement and awareness in taxonomy by creating portable, educational exhibits. These resin dioramas, accompanied by QR codes linking to expert videos, debunk misconceptions about taxonomy and highlight its significance. By focusing on marine biodiversity, EpoXonomy© supports the United Nations Sustainable Development Goal 14: Life Below Water, promoting ocean literacy and conservation.

2.7 Youth Empowerment and Marine Conservation Through the Sustainable Ocean Alliance

The Sustainable Ocean Alliance (SOA) empowers young people to develop and implement innovative solutions for ocean conservation. Established in 2014, SOA has built a global network of young leaders, entrepreneurs, and advocates dedicated to addressing marine challenges. SOA's programs, including the Ocean Solutions Accelerator, Ocean Leadership Program, and Microgrants, support various initiatives aimed at restoring ocean health. EpoXonomy©, as a recipient of SOA's microgrants, exemplifies the potential of youth-led projects to enhance public engagement and contribute to marine conservation. By fostering a new generation of ocean stewards, SOA plays a crucial role in ensuring the long-term sustainability of marine ecosystems.

2.8 Adapting to the Pandemic: Virtual Exhibitions for Marine Biodiversity Awareness

The Covid-19 pandemic necessitated a shift to virtual platforms for educational and outreach activities. In response, the EpoXonomy© project organized a virtual exhibition during World Ocean Week 2021. This online event allowed participants to explore marine biodiversity through interactive, digital displays, despite the constraints of physical distancing. The virtual exhibition provided a platform for students to showcase their curatorial skills and engage the public in marine conservation issues. By leveraging digital tools, the exhibition reached a broader audience and highlighted the importance of preserving marine biodiversity. This adaptation not only ensured continuity in public engagement but also demonstrated the potential of virtual platforms in scientific outreach.

3.0 METHODS

3.1 Framework of MMB3314 Elective Course

To address misconceptions about taxonomy and emphasize its critical role in marine biodiversity conservation, the elective course MMB3314: Biological Classification of Marine Organisms was developed. Over a 14-week period, 51 students participated in this 3-credit hour course. The course integrates theoretical and practical aspects of taxonomy and is structured around three core learning outcomes (CLOs). These CLOs are designed to build a comprehensive understanding of systematics and its applications. CLO1 focuses on students' ability to elaborate on the systematics, evolution, and biology of marine organisms based on their common and differentiating characteristics. CLO2 emphasizes the demonstration of laboratory skills for the management and conservation of biological specimens through appropriate taxonomic methods and software, ensuring ethical practices. CLO3 involves organizing outreach programs that apply classroom theories and laboratory skills into public exhibitions, aiming to raise awareness about marine biodiversity.

The course content is methodically structured to sequentially address each CLO, preparing students for a culminating virtual exhibition project. The theoretical component of the course covers a wide range of topics, including an introduction to taxonomy, biological nomenclature, species concepts, literature search methods, the role of museum collections, and the intricacies of reading and writing species descriptions. Additional topics include the International Code of Zoological Nomenclature (ICZN) and other regulatory bodies, type specimens and their significance, taxonomic keys, and methods of classification such as phenetics, cladistics, and

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phylogenetics. Each chapter incorporates online case studies conducted via Cisco Webex, allowing students to engage in group discussions and present their understanding to their peers. This interactive format facilitates immediate feedback and on-the-spot revision, enhancing the learning experience. The inclusion of guest experts through "industry in the classroom" sessions further enriches students' understanding by providing real-world insights into taxonomy and systematics. Students' comprehension is evaluated through a quiz, a test, and a final exam.

In response to the pandemic, which restricted laboratory access, the course incorporated remote practical exercises by mailing toolkits to students. These toolkits enabled students to practice essential laboratory skills at home. The practical component included several laboratory lessons, starting with wet specimen preparation, where students followed instructions from a trained curator and created 5-minute videos demonstrating the preparation steps. This was followed by dry specimen preparation of molluscs and arthropods, again with instructional videos produced by the students. Subsequent lessons covered collection storage and conservation treatment of the prepared specimens, and database management divided into two parts: extracting data from the Ocean Biogeographic Information System (OBIS) and data proofing using the World Register of Marine Species (WoRMS). Students transferred their data into a standardized database template, verified scientific names, and provided the accepted nomenclature and AphiaID for each species. Their practical skills were assessed through detailed lab reports and a comprehensive rubric evaluating their overall understanding of the laboratory work.

For the outreach component, students participated in the virtual exhibition "EpoXonomy©," where each student selected a marine specimen of ecological or economic significance and created a 3-minute video to highlight its importance. These videos, presented in various creative formats, were evaluated based on their content and the students' ability to convey the significance of their specimens effectively. The exhibition was designed in collaboration with curators and marine experts from RRC and UMT, who prepared educational resin blocks and specimens. Each resin block was paired with a unique QR code linked to educational videos and information, facilitating public engagement and awareness during the exhibition hosted on Facebook during World Ocean Week.

The EpoXonomy© initiative aimed to bridge the gap in taxonomy literacy through interactive and artistic presentations. The objectives included selecting 50 different specimens for the exhibition, producing educational kits with QR codes, and engaging at least 20% of the public through the virtual exhibition. The success of these objectives was measured by the number of specimens presented, the production of educational materials, and the level of public engagement as indicated by views and survey responses.

3.2 Design of EpoXonomy© For the Virtual Exhibition

The development of EpoXonomy© for the virtual exhibition was guided by trained curators and marine experts from RRC and UMT. This initiative aimed to create educational resin blocks and specimens for various purposes, including classroom teaching, laboratory exercises, exhibitions, and educational souvenirs. Each resin block was paired with a unique QR code linking to educational videos and information prepared by students and contributed by research experts. The project involved remote collaboration and coordination among students, educators, and experts to ensure the successful implementation of the virtual exhibition.

The objectives of the EpoXonomy© initiative were multifaceted. Firstly, it aimed to bridge the gap in fundamental taxonomy knowledge by presenting different marine specimens aligned with the themes of the Sustainable Ocean Alliance (SOA). Secondly, the initiative sought to produce educational kits containing QR-coded resin blocks of marine organisms for teaching, exhibition, and research purposes. Lastly, it aimed to create awareness among the public through advertising, exhibitions, and interactive materials, with a target of engaging at least 20% of the audience.

To achieve these objectives, students were tasked with selecting and showcasing marine specimens of ecological or economic significance. Each student created a 2-minute video highlighting the uniqueness and importance of their chosen species. These videos were used to educate the public about marine biodiversity and its conservation during the virtual exhibition. The exhibition was hosted on Facebook during World Ocean Week, attracting visitors from diverse backgrounds and promoting taxonomy literacy through interactive and artistic presentations.

The success of the EpoXonomy© initiative was evaluated based on several metrics, including the number of specimens presented, the production of educational materials, and the level of public engagement. Through careful planning and execution, the initiative aimed to enhance public awareness of marine biodiversity and foster a greater appreciation for taxonomy and conservation efforts.

3.3 Questionnaire for EpoXonomy©

The study included pre- and post-exhibition surveys to evaluate the impact of the EpoXonomy© initiative. The pre-exhibition survey was divided into three sections: Section A gathered demographic information, Section B assessed knowledge, awareness, preparedness, participation, and innovation, and Section C included questions about the marine organisms featured in the exhibition. The post-exhibition survey repeated Sections B and C to measure changes in respondents' awareness and understanding, providing a comprehensive assessment of the initiative's effectiveness.

To select respondents for the pre- and post-exhibition surveys evaluating the impact of the EpoXonomy© initiative, a systematic approach was adopted. The target population comprised individuals who engaged with the virtual exhibition during World Ocean Week. For the pre-exhibition survey, respondents were recruited through various channels such as social media announcements, email invitations to relevant organizations or groups, and direct outreach to educational institutions or marine conservation networks. These recruitment efforts aimed to reach a diverse audience interested in marine biodiversity, conservation, and taxonomy. Additionally, participants were encouraged to share the survey with their networks to broaden the reach and diversity of respondents. To ensure a representative sample, efforts were made to target

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individuals from different demographic backgrounds, including age, gender, educational attainment, and geographic location. This diversity helped capture a wide range of perspectives and experiences related to marine conservation and taxonomy. Following the virtual exhibition, the same recruitment channels were utilized to invite participants to complete the post-exhibition survey. Respondents who had previously participated in the pre-exhibition survey were encouraged to provide feedback on their experience after engaging with the EpoXonomy© initiative. This allowed for a comparison of responses before and after exposure to the virtual exhibition, enabling an assessment of changes in knowledge, awareness, and attitudes regarding marine biodiversity and taxonomy. Overall, the selection of respondents for the pre- and post-exhibition surveys was guided by the goal of obtaining a representative sample of individuals interested in marine conservation and taxonomy, thereby ensuring the robustness and validity of the evaluation process for the EpoXonomy© initiative.

3.4 Pre and Post test

The study included pre- and post-exhibition surveys to evaluate the impact of the EpoXonomy© initiative. The pre-exhibition survey was divided into three sections:

Section A: Gathered demographic information.
Section B: Assessed knowledge, awareness, preparedness, participation, and innovation.
Section C: Included questions about the marine organisms featured in the exhibition.

For the pre-exhibition survey, respondents were recruited through various channels such as social media announcements, email invitations to relevant organizations or groups, and direct outreach to educational institutions or marine conservation networks. These recruitment efforts aimed to reach a diverse audience interested in marine biodiversity, conservation, and taxonomy. Participants were encouraged to share the survey with their networks to broaden the reach and diversity of respondents. The target population comprised individuals who engaged with the virtual exhibition during World Ocean Week.
The post-exhibition survey repeated Sections B and C to measure changes in respondents' awareness and understanding, providing a comprehensive assessment of the initiative's effectiveness. Following the virtual exhibition, the same recruitment channels were utilized to invite participants to complete the post-exhibition survey, allowing for a comparison of responses before and after exposure to the virtual exhibition.

3.5 Validity and Reliability Test

The instruments underwent validation and reliability testing to ensure their suitability for the study. Reliability analysis, using Cronbach's alpha, was conducted for each variable, including knowledge, awareness, preparedness, participation, and innovation. Results revealed high reliability coefficients for all variables: knowledge (α = 0.904), awareness (α = 0.973), preparedness (α = 0.918), participation (α = 0.892), and innovation (α = 0.944) (Refer Table 1). As all coefficients exceeded the threshold of 0.70, indicating acceptable reliability, the scales used in the study were deemed reliable and valid (DeVellis, 2003).

Table 1. Reliability Test

Variable	Cronbach's Alpha	Items
Knowledge	.904	11
Awareness	.973	4
Preparedness	.918	5
Participation	.892	3
Innovation	.944	3

4.0 RESULT AND DISCUSSION

The study utilized a two-part questionnaire consisting of pre- and post-surveys. A total of 502 responses were collected for the pre-survey, while the post-survey garnered 323 responses. However, to ensure consistency in data analysis, only responses from participants who completed both questionnaires were considered valid, resulting in a total of 297 responses for further analysis. This stringent criterion was applied to maintain the integrity of the data and to enable accurate comparisons between pre- and post-exhibition perceptions and attitudes regarding marine biodiversity and taxonomy.

4.1 Normality Test

The normality test was conducted to assess the skewness and kurtosis values of the variables. As recommended by Kline (2011), skewness values exceeding three (>3) and kurtosis values surpassing ten (>10) may indicate potential issues, with values above 20 suggesting more significant problems. In adherence to these guidelines, it was ensured that the absolute values of skewness and kurtosis for all variables in the study remained below three (<3) and ten (<10), respectively. Examination of the data presented in Table 2 confirms that the skewness and kurtosis values fall within the acceptable ranges, with skewness ranging from -1.272 to 0.778 and kurtosis ranging from -0.165 to 1.731.

Table 2. Skewness and Kurtosis

Variable	Skewness		Kurtosis	
	Statistic	Std. Error	Statistic	Std. Error
Knowledge	-0.025	0.141	-0.165	0.282
Awareness	-1.272	0.141	1.731	0.282
Preparedness	-0.665	0.141	0.543	0.282

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Participation	0.778	0.141	-0.167	0.282
Innovation	-0.657	0.141	0.600	0.282

4.2 Descriptive Statistics (Mean & Standard Deviation)

Descriptive statistics, including mean and standard deviation, were calculated for the variables from both the pre- and post-surveys. Table 3 illustrates the mean values for knowledge, awareness, preparedness, participation, and innovation variables. In the post-survey, mean values were consistently higher than those in the pre-survey: knowledge (2.99 to 3.90), awareness (4.09 to 4.35), preparedness (3.72 to 4.04), participation (2.05 to 2.97), and innovation (3.75 to 4.12). This suggests an overall improvement in respondents' perceptions and understanding following their participation in the virtual exhibition.

Table 3. Mean and Standard Deviation

Variable	Pre		Post	
	Mean	Std. Deviation	Mean	Std. Deviation
Knowledge	2.99	0.80295	3.90	0.79939
Awareness	4.09	0.92054	4.35	0.70467
Preparedness	3.72	0.84552	4.04	0.83515
Participation	2.05	1.02131	2.97	1.24351
Innovation	3.75	0.88278	4.12	0.78258

4.3 Demographic Profile

Malaysian nationals (96.6%), with a small proportion representing other nationalities (3.4%). Regarding locality, a significant portion of respondents hailed from urban areas (53.5%), followed by sub-urban areas (37.0%), urban coastal regions (5.4%), and sub-urban coastal locales (4.0%). Ethnically, the majority identified as Malay (88.6%), with smaller percentages representing other ethnicities, including Chinese (1.3%), Indian (2.7%), and others (7.4%). Age distribution among respondents was highest in the 21-30 years range (76.4%), followed by 11-20 years (11.1%), 41-50 years (5.1%), above 51 years (4.4%), 31-40 years (2.7%), and below 10 years (0.3%). The educational attainment of respondents varied, with the majority holding undergraduate degrees (64.3%), followed by certificate/ STPM/ diploma/ matriculation/ foundation qualifications (17.8%), secondary school education (12.8%), postgraduate degrees (4.4%), and primary school education (0.7%). Occupationally, most respondents identified as students (77.1%), followed by those employed in the private sector (8.4%), government sector (6.4%), self-employed (4.4%), retired individuals (1.0%), and others (2.7%).

Table 4. Demographic Profile of Respondents

Demography	Category	Frequency (n=297)	Percent (%)
Gender	Male	77	25.9
	Female	220	74.1
Nationality	Malaysia	287	96.6
	Others	10	3.4
Locality	Urban	159	53.5
	Urban Coastal	16	5.4
	Sub-urban	110	37.0
	Sub-urban Coastal	12	4.0
Ethnicity	Malay	263	88.6
	Chinese	4	1.3
	Indian	8	2.7
	Others	22	7.4
Age	Below 10 years	1	0.3
	Between 11-20 years	33	11.1
	Between 21-30 years	227	76.4
	Between 31-40 years	8	2.7
	Between 41-50 years	15	5.1
	Above 51 years	13	4.4
Education Level	Primary School	2	0.7
	Secondary School	38	12.8
	Certificate/ STPM/ Diploma/Matriculation/ Foundation	53	17.8
	Undergraduate	191	64.3
	Postgraduate	13	4.4
Occupation	Student	229	77.1
	Government	19	6.4
	Private	25	8.4
	Self-employed	13	4.4
	Retired	3	1.0
	Others	8	2.7

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Table 5 presents insights into respondents' participation and motivations regarding virtual exhibition events. It indicates that only a small proportion (3.4%) of respondents had previous experience with similar virtual exhibitions. The primary motivator for attending this virtual exhibition was the opportunity to enhance knowledge (82.2%), followed by gaining experience (55.6%), raising awareness (53.9%), passing the time (38.0%), personal interest (31.6%), improving skills (29.0%), family influence (16.2%), subject suitability (6.1%), and other factors (1.7%). Among the channels through which respondents learned about the virtual exhibition, friends played a prominent role (63.0%), followed by family members (20.5%), social media platforms (8.8%), self-discovery (7.4%), and workplace engagement (0.3%).

Table 5. Responses to The Virtual Exhibition

Statement	Category	Frequency (n=297)	Percent (%)
Have you participated in a similar virtual exhibition event?	Yes	10	3.4
	No	287	96.6
Main Factors That Motivated to Attend This Virtual Exhibition:			
Improved Knowledge	Yes	244	82.2
	No	53	17.8
Improved Skills	Yes	86	29.0
	No	211	71.0
Raise Awareness	Yes	160	53.9
	No	137	46.1
Gain Experience	Yes	165	55.6
	No	132	44.4
Family	Yes	48	16.2
	No	249	83.8
Subject Suitability	Yes	18	6.1
	No	279	93.9
Interest	Yes	94	31.6
	No	203	68.4
To Pass the Time	Yes	113	38.0
	No	184	62.0
Others	Yes	5	1.7
	No	292	98.3
How did you know about this virtual exhibition event?	Self	22	7.4
	Friends	187	63.0
	Family	61	20.5
	Workplace	1	.3
	Social media	26	8.8

4.4 General Knowledge about Marine Organisms

Table 6 presents data regarding respondents' general knowledge about marine organisms exhibited during the Virtual EpoXonomy Exhibition. The table includes ten statements assessing participants' understanding, with responses categorized as "Yes" or "No" for each statement. Analysis of the pre- and post-survey responses indicates an overall improvement in respondents' comprehension, except for question 9. For question 1, regarding the commercial value of mud crabs, 52.5% of respondents answered "Yes" during the pre-survey, which shifted to 37.0% in the post-survey. Conversely, the percentage of "No" responses increased from 47.5% to 63.0%, indicating a 15.5% improvement in understanding. Similarly, question 2, concerning dead zones and their impact on organisms like the Common Ponyfish, saw a 10.4% increase in correct responses from pre- to post-survey. Questions 3, 5, 6, and 7 also showed notable improvements, with correct responses increasing by approximately 10% to 17.1%. However, question 9 saw a decrease in understanding from pre- to post-survey, with the percentage of correct responses dropping by 17.2%. This discrepancy is attributed to the misunderstanding that the decline in the money cowrie population was due to climate change, whereas it was primarily a result of human intervention. Overall, the findings suggest that the virtual exhibition effectively enhanced participants' knowledge of marine organisms, as evidenced by the increased percentage of correct responses across most questions.

Table 6. General Knowledge about Marine Organisms That Have Been on Display Throughout the Virtual Epoxonomy Exhibition

Statements	Category	Pre		Post	
		(n=297)	(%)	(n=297)	(%)
Mud crab (*Scylla olivacea*) have the lowest commercial value and are often discarded	Yes	156	52.5	110	37.0
	No	141	47.5	187	63.0

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by fishermen.					
Deadzone is an area where oxygen is absent (hypoxia) and most organisms such as the Common Ponyfish *(Leiognathus equula*) becomes deprived and dies leaving the whole area inhabitable.	Yes	240	80.8	271	91.2
	No	57	19.2	26	8.8
Acropora sp. was one of the few corals that was severely affected by the most damaging coral global bleaching event in 2017.	Yes	219	73.7	249	83.8
	No	78	26.3	48	16.2
By-the-wind-sailor (*Velella velella*) is a true jellyfish that capture prey by its long tentacles	Yes	173	58.2	157	52.9
	No	124	41.8	140	47.1
Pagoda cup coral (*Turbinaria peltata*) is most commonly threatened by international trades and are heavily harvested for the aquarium trade.	Yes	209	70.4	260	87.5
	No	88	29.6	37	12.5
	Yes	186	62.6	244	82.2
Knotted fan coral (*Melithaea ochracea*) is found in shallow waters and feeds on plankton at night by extending their tentacles.					
	No	111	37.4	53	17.8
Blue, red and black corals (*Heliopora coerulea* - Corallium - Antipatharians) is a home to dinoflagellates or tiny plant cells called zooxanthellae that helps in providing food to corals through photosynthesis.	Yes	209	70.4	254	85.5
	No	88	29.6	43	14.5
Thorn-like spikes on the Crown of Thorn Starfish (*Acanthaster planci)* are mainly used as a mating attraction to help increase their reproductive success.	Yes	177	59.6	138	46.5
	No	120	40.4	159	53.5
Money cowrie (*Monetaria moneta*) was rapidly devalued as a currency in the late 19th century as	Yes	188	63.3	239	80.5
	No	109	36.7	58	19.5

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the species started to reduce in population due to climate change.					
Green seaweed (*Ulva* sp.) is an edible green alga that is also known as "sea lettuce" distinguished from its blade-like leaves that allows rapid growth in nutrient-rich waters.	Yes	238	80.1	266	89.6
	No	59	19.9	31	10.4

5.0 CONCLUSION

In conclusion, the EpoXonomy© initiative emerges as a multifaceted tool with far-reaching benefits across various stakeholders, including academicians, industrial collaborators, scientists, researchers, university and school students, as well as the general public. By delving into the fundamentals of taxonomy, EpoXonomy© not only lays the groundwork for understanding other scientific disciplines but also fosters a profound appreciation for the rich diversity of marine life and its ecological and economic significance. Through a blend of reflective observation and abstract conceptualization, participants gain a deeper understanding of why taxonomy is pivotal in elucidating biological, ecological, and economic aspects. This comprehension is further enriched through real-life case studies, inviting experts to share insights from their respective fields, thereby bridging the gap between theoretical knowledge and practical applications. The hands-on laboratory sessions offered by EpoXonomy© provide students with invaluable experience in handling diverse biological specimens, expanding their scientific horizons beyond what traditional classroom settings offer. Moreover, these sessions cultivate an appreciation for the meticulous work of curators, potentially inspiring students to pursue careers in related fields. The initiative also fosters creativity and entrepreneurship, empowering students to design resin blocks for educational or commercial purposes, thus nurturing innovative thinking and practical skills. Perhaps most significantly, EpoXonomy© empowers students to become agents of change through citizen science exhibitions, where they apply their acquired knowledge to address societal issues and promote environmental awareness. By engaging with the broader community, EpoXonomy© transcends traditional educational boundaries, leaving a lasting impact on both participants and society at large. Overall, EpoXonomy© stands as a beacon of interdisciplinary learning and community engagement, heralding a new era of marine biodiversity conservation and scientific exploration.

6.0 STUDY LIMITATIONS

Several limitations were encountered during this study, offering valuable insights for future research endeavors. Firstly, the study was conducted within the constraints of limited staffing at the South China Sea Repository and Reference Centre (RRC). A more immersive educational experience could have been achieved through the integration of technology, such as a 360º virtual tour of the RRC showcasing specimens with interactive features for viewers to access detailed information and educational videos. Incorporating expertise from information technology (IT) and Artificial Intelligence (AI) specialists could enhance content delivery, potentially garnering international interest. While the virtual exhibition of EpoXonomy© proved successful, there remains an inherent value in providing physical, hands-on experiences for students within a renowned natural heritage repository like the RRC. Suggestions for future improvements include hybrid classroom sessions and industrial talks, alongside the incorporation of small groups of students into the RRC's labs to adhere to strict Standard Operating Procedures (SOPs) in museum conservation and management, offering exposure to a diverse range of biological specimens. Another limitation pertained to concerns regarding participant engagement in the pre and post surveys. While the difference was not significant, ensuring consistent voluntary participation throughout the survey process could enhance data accuracy. Future studies may consider strategies to streamline surveys without compromising depth or to incentivize participation. In summary, while the study showcased the efficacy of EpoXonomy©'s virtual exhibition, there are opportunities for refinement and expansion in future iterations, including technological enhancements, hands-on learning experiences, and improved survey methodologies to ensure comprehensive data collection.

7.0 COMPLIANCE WITH ETHICAL STANDARDS

This study has been prepared accordingly and compliance with ethical standards.

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9.0 CONFLICT OF INTEREST

All the authors are free from any conflicts of interest in writing this manuscript.

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