Aquatic biodiversity education in higher learning: developing interdisciplinary curricula to foster sustainability in aquatic research

Nargiza Yulanova[1*]; Adamboy Masharipov[2]; Farzona Olloqulova[3]; Madinabonu Karimova[4]; Maftuna Abdullayeva[5]; Charos Jalilova[6]; Dilshod Voxidov[7]; Abdujolol Boqiyev[8]

Received: 17 August 2025; Revised: 05 October 2025; Accepted: 05 November 2025; Published: 20 December 2025

Abstract

The preservation of ecosystems depends on aquatic biodiversity, although implementing solutions is a challenge. Advanced learning can bring profound change, and planners must advocate for greater cross-disciplinary collaboration. In this, the authors look to deploy the engineering of curricula for cross-disciplinary education aimed at conservation of aquatic ecosystems and biodiversity at tertiary education institutions. In the integrated approaches, policy analysis, biology, environmental science, and the relevant administrative technology to aquatic ecosystems, the aimed curricula must prepare learners to interrogate better the existing perennial frames around and the aggressively and actively declining biodiversity. The authors here advocate for collaboration between students and other scientists doing field work and cross-disciplinary projects in a deep immersion in a real ecosystem to understand the fundamentals of experiencing the given biodiversity. Besides, the contribution of sustainability to aquatic research has been emphasized, with reference to the need to create mechanisms that balance the conservation of ecosystems with the demands of human development. It also explains the importance of a curriculum that requires both theoretical knowledge and hands-on skills in aquatic research, conservation, and policy-making in preparing students to take up

1*- Tashkent University of Information Technologies named after Muhammad al-Khwarizmi, Tashkent, Uzbekistan. Email: yulan.nargiz@gmail.com, ORCID: https://orcid.org/0009-0000-9174-1899
2- Urgench State University, Urgench, Uzbekistan. Email: adamboymasharipov1979@gmail.com, ORCID: https://orcid.org/0000-0003-0178-3222
3- Termez State Pedagogical Institute, Termez, Uzbekistan.
Email: olloqulovafarzona93@gmail.com, ORCID: https://orcid.org/0009-0004-1492-8683
4- Fergana Public Health Medical Institute, Tashkent, Uzbekistan.
Email: karimova94madina@gmail.com, ORCID: https://orcid.org/0009-0006-0486-1109
5- National Pedagogical University named after Nizami, Tashkent, Uzbekistan.
Email: maftunaabdullayeva916@gmail.ru, ORCID: https://orcid.org/0000-0002-7020-1313
6- Bukhara State Pedagogical Institute, Bukhara, Uzbekistan.
Email: jalilovacharosxon@gmail.com, ORCID: https://orcid.org/0009-0006-6693-9688
7- Samarkand State Medical University, Samarkand, Uzbekistan.
Email: aziza.anisa.asaliya@gmail.com, ORCID: https://orcid.org/0009-0002-0912-3747
8- National Research University, Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, Tashkent, Uzbekistan. Email: abdujolol@mail.ru, ORCID: https://orcid.org/0009-0006-9914-3600
*Corresponding author
DOI: 10.70102/IJARES/V5I2/5-2-63

careers in the same field. Higher education institutions can establish an interdisciplinary partnership to help build a more well-rounded understanding of the complex nature of problems in aquatic biodiversity and to join the global community of sustainable aquatic management. The identified gaps in conservation of the aquatic environment strongly justify the need for integrating more complex and comprehensive interdisciplinary courses at higher education institutions.

Keywords: Interdisciplinary education, Conservation, Aquatic conservation, Enhancing curricula, Diversity of life in water, Sustainability, Higher education

Introduction

The health of ecosystems and the conservation of water on Earth are both deeply connected to aquatic ecosystems and biodiversity. Problems of pollution, habitat destruction, and climate change, coupled with new growing global environmental issues, make marine biodiversity one of the most endangered. Each of these issues will only get worse if education and research are not deployed. Higher education is well-suited to creating focused, new interdisciplinary and integrative marine education and research (Mokski *et al.*, 2023; Oliveira *et al.*, 2025). These will prepare new generations of researchers, conservationists, and decision-makers with the methods of interdisciplinary environmental research, amalgamating science, policy, and technology to support sustainable marine research and management (Annan-Diab and Molinari, 2017; Podgórska and Zdonek, 2024).

Interdisciplinary innovative approaches are needed to counter the arising issues pertaining to the conservation of biodiversity in water bodies (Mohameed *et al.*, 2025; Ajiga *et al.*, 2025). The conservation of interlinked water ecosystems, and the four disciplines of its biology, chemistry, geography, and environmental policy, entails understanding and invites the construction of modules precisely designed and deployed (Vincent and Focht, 2011). Such construction augments and encourages targeted institutions in the ecosystems at this academic tier. Such an institution augments and encourages learners to gras conduct scientific inquiry into the aquatic biodiversity as well as the water-related socio-geo, socio-politico, and socio-economic, and socio-environmental processes (Tupas, Matsuura and Muryuno, 2025). This cross-cohesive approach not only intersects cross-disciplines of learning, but also scaffolds learners at the interface of cross-sectional issues fundamental in the planning and almost the same in execution of the initiative pertaining to the conservation of the aquatic ecosystems and targeting and focusing on modules such as the above-cited, which, notwithstanding their absence of applied contents, such as the elements, which are practically oriented, are geared to the rich fieldwork, practical, interdisciplinary collaborative elements, which are vital to the workout of the conservation problem posed in the world (Consorte-McCrea and Newing, 2015).

The sustainability of the aquatic biodiversity depends on research centered on sustainability and the involvement of different stakeholders. Curriculum development based on sustainability in aquatic research enables students to see the fine line between conservation of the ecosystem and man (Ajiga *et al.*, 2025; Bacon *et al.*, 2011). Whether through policy design, ecosystem repair, or technological innovations, sustainability within the higher education academic program is essential for formulating responsible and efficient aquatic conservation initiatives (Scoarize *et al.*, 2022). With the interdisciplinary education on aquatic biodiversity as institutions adopt multidisciplinary education, the institutions will be in a better position to produce people who may address the urgent demand of sustainable management of aquatic resources in order to promote the long-term health of aquatic environments all over the world (Vincent and Focht, 2011; Simanjuntak, Rafli and Utami, 2024).

This paper is structured in the following manner: Section II is a review of the literature available on the integration of sustainability in the context of aquatic education, with a special emphasis on interdisciplinary approaches. Section III elaborates on the approach to design and development of a multidisciplinary curriculum on aquatic biodiversity education, that is, curriculum design, experiential learning, and integrating sustainability. In Section IV, the results of the experiment are provided, and the emphasis is placed on the effects of the curriculum on the engagement of the students, their retention, and the practicality of the knowledge in the real world. Last but definitely not least, Section V gives a recap on the long-term advantages of the interdisciplinary approach and emphasizes its significance in equipping students to work in aquatic research and conservation fields, as well as proposing increased curriculum development to allow sustainable marine management (De Beer and Msezane, 2024; Nasirpour *et al.*, 2024).

Literature Review

Aquatic biodiversity has mainly been acknowledged as significant in ecosystem health, as has been known in the environmental research area. Multiple studies emphasize the importance of such water bodies as wetlands, rivers, lakes, and oceans in controlling climate, hosting biodiversity, and offering vital ecosystem services, such as water purification and carbon absorption. Aquatic concerns are being further complicated by habitat loss and artisanal fisheries, as well as urbanization and urban fishing, and the rampant evolution of industrialization and pollution. There is no doubt that the safeguarding and functioning of these systems nourish the roots of a civilization. In this light, the integration of interdisciplinary, cross-sectoral, and sustainable approaches in teaching and research in ecology, and especially the marine and ocean ones, seems to more than adequately address this concern (Sen and Malhotra, 2025). Of various, perhaps the most pivotal is the crafting of harmonious multi-dimensional structures, whereby active cooperation is attainable. This is most pronounced in the arms of practical and sustainable conservation thinking. These embrace educational systems as the most radical intervention points for the future custodians of the planet, under a model of sustainable and ecologically positive development, paired with the stringent control and wealth of their nation (Strachan *et al.*, 2023).

The currently available literature attempts to provide evidence of the interdisciplinary approach to the complexity of conserving aquatic biodiversity (Verma and Mehta, 2024). In some instances, the traditional academic 'silos' have inhibited students' understanding of the marine ecosystems as an integrated whole. There has, however, been the proposal of an interdisciplinary approach to teaching that cuts across environmental science, marine biology, policy, and ecology (Anapana *et al.*, 2025). This approach increases the student's preparedness to tackle issues of habitat restoration, pollution, and biodiversity loss. Furthermore, and perhaps most importantly, field studies and research have been shown to be effective in providing students with the theoretical and practical knowledge of aquatic systems. Practice and theory, particularly the former in environmental conservation of waters, integrated together, improve students' problem-solving skills and employability.

Sustainability is an integral part of a college/university curriculum because it allows for the conservation of the remaining biodiversity in water bodies (Smitha, Mani and Arumugam, 2025; Goodale, 2020). Environmental policymakers and those in sustainable development have noted that there is a need to formulate viable policies that are able to reconcile various ecological, societal, and economic issues (Miranda *et al.*, 2016). Additionally, the recent advancements in technology in aquatics such as remote sensing and modeling have technology aquatics remote sensing and modeling and have greatly improved our ability to assess and plan strategies for the conservation and management of aquatic ecosystems. There is an imbalance in the marine research curriculum that intends to train students in the different methods of sustainable management of aquatic resources (Abdolabade *et al.*, 2017; Gaard, Blades and Wright, 2017). Such curricula/frameworks facilitate the construction of interdisciplinary frameworks that address the more complex challenges, such as water scarcity, climate change, and the loss of biodiversity (Parker, 2010). Aquatic management seems to be the issue the world is facing lately, and that is the reason why higher learning institutions need to update the core of their syllabus on a regular basis (Spelt *et al.*, 2009). The environmental position of the world is changing constantly because of the global need to increase sustainable management, especially regarding aquatic resources.

Methodology

Curriculum Design and Development

The main objective of this study was to design and develop an interdisciplinary curriculum that emphasized aquatic biodiversity education at the institutions of higher learning. The curriculum was formulated by incorporating the basic ideas of various subjects, such as environmental science, marine biology, ecology, aquatic conservation, and sustainability studies. In order to make the curriculum relevant and practical, the curriculum was developed in consultation with aquatic research experts, the faculty of policy studies, and technology departments. Selecting the learning modules that focus on both the theoretical background of the aquatic ecosystems and the practical methods of conservation was emphasized. The curriculum will be designed to encourage an interdisciplinary and holistic study of aquatic biodiversity, which allows students to study the sustainable management of aquatic environments by means of real-life cases and multidisciplinary methods.

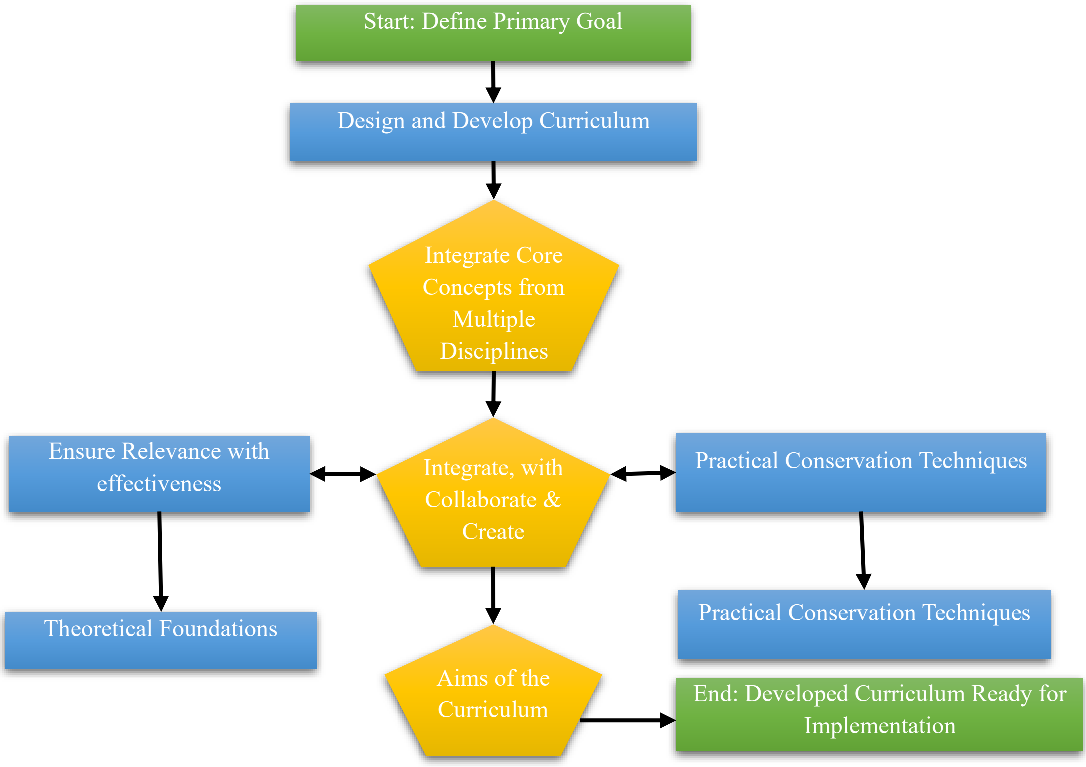

Figure 1: Aquatic biodiversity education interdisciplinary curriculum design process.

Figure 1 shows the necessary actions to work out the new interdisciplinary curriculum. The first phase would start with the Primary Goal of design and development, which directly results in the Integration of Core Concepts of Multiple Disciplines. A critical step of Collaboration with experts and faculty transfers the resulting curriculum to a relevant and practical phase. These modules pay the same attention to Theoretical Foundations and Practical Conservation Techniques. This progression also leads to the Aims of the Curriculum, which is to encourage sustainable management of holistic understanding, which leads to the Developed Curriculum Ready to Implement.

Learning Process and Teaching/Instructional Strategies

Adopted blended learning methodologies aim to promote active learning and increase students' motivation towards the learning materials related to aquatic ecosystems and biodiversity. The selected method was combining face-to-face teaching with experiential techniques such as fieldwork, laboratory work, and the use of virtual learning environments. Students had the opportunity to engage in practical activities such as water sampling, restoration of ecosystems, and monitoring of aquatic ecosystems, and also participated in the tracking of technology-assisted aquatic systems. These activities and more were performed with the help of virtual reality systems and other digital immersive platforms, which simulated aquatic ecosystems in virtual environments. Such approaches are essential in artificial settings where natural water bodies are absent and can support creativity in teaching sustainability in the study of aquatic ecosystems.

Long-term Impact: Sustainability Integration

Incorporation of sustainability principles in the aquatic education curriculum through skeletal construction was woven into the course instruction as the achievement metrics were one of the focal elements of the methodology. Through systems thinking, the intricacies of aquatic biodiversity as well as environmental sustainability were appreciated through analyzing sustainable management of biodiversity and biodiversity conservation case studies. The students devised solutions to real-life challenges affecting aquatic ecosystems, such as habitat degradation, climate change impact, and many others. Most profound change of the curriculum over the next few years was understood through longitudinal cross-silo follow-up surveys and interviews of graduates along their career paths pursued in aquatic research and conservation, sustainable passive aquatic practices, and the role those practices played in their professional activities.

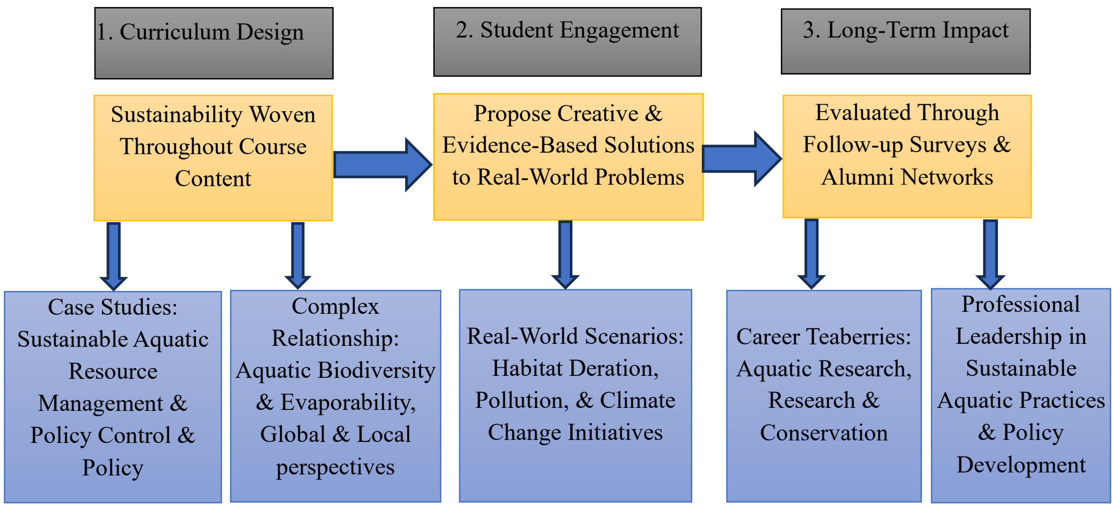

Figure 2: Curriculum framework and the sustained impact on education around aquatic sustainability.

Figure 2 shows the structure of an interdisciplinary curriculum that addresses the sustainability of aquatic systems. The Curriculum Framework has been constructed and partitioned into Curriculum Design, Student Engagement, and Sustained Impact. In Curriculum Design, sustainability is infused into the curriculum's content by drawing on case studies of the management and policy of aquatic resources. In the second phase, Student Engagement, the aim is to make students the focal point of the generation of creative, evidence-based responses to global challenges, particularly those to do with climate change and fisheries. Sustained Impact is the final phase, which is assessed using longitudinal studies and alums surveys that track graduates into the fields of aquatic research, policy development, and conservation.

Experimental Results

Impact of Interdisciplinary Curriculum on Student Knowledge

The outcome regarding the application of interdisciplinary curriculum on the education of aquatic biodiversity detected significant advances in the participants' knowledge acquisition across the curriculum. How many participants improved on the Marine Biodiversity Conservation and Socially Responsible Sustainable Management Ecosystem Practices Assessments, and the pre- and post-assessments on aquatic ecosystems were the strongest indicators of how much progress had been made in ecosystem assessments and how much progress had been achieved. Students seemed to grasp the complex relationships between environmental sustainability and biodiversity much more easily. Students exposed to the integrated concepts of ecological science, along with components of ecology and aquatic technology, achieved higher scores across all theory/practical papers, thereby reinforcing the notion that the cross-disciplinary approach enhanced instructional outcomes.

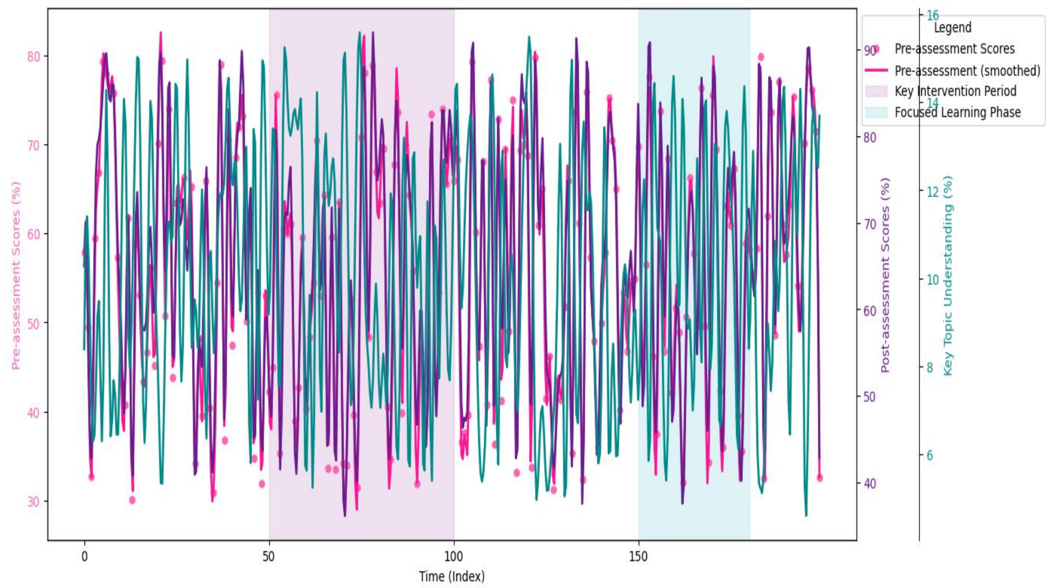

Figure 3: Multimodal interaction: correlational profiles between engagement, time invested, and learning outcomes of the aquatic learning module.

In Figure 3, student engagement metrics were combined with time allocation data to perform a weighted resource allocation analysis of five student activities across the Project-Based Learning methodology. Average Student Engagement Scores on a 1-5 scale (left axis) were mixed. In contrast, Average Student Time Spent (Hours, right axis) was analyzed with custom software to extract a multifactor time-engagement continuum. On the time spent versus time engagement scale, the results show that Water Sampling is the highest (value of 4.8) and hence the strongest reason for a direct positive correlation with time spent (15 hours). In contrast to captured time spent ratios, VR

Inline Simulations registers as the least engaging (as low as -0.2) and subordinate to engagement. The low correlation visible also needs to be paired. The time spent on the activity line indicates a traversal pattern below the engagement line that constitutes a target for three metrics - Field and Study, Habitat Restoration. The data highlights a key assumption for schools with allocated time - the VR simulations' minimum engagement values are spent, while the intention is primarily to raise both metrics.

Student Interaction and Involvement in Practical Learning

The experimental data have raised several critical issues, one of which concerns the level of student interest and participation in learning activities such as field studies and laboratory sessions. Collecting water samples, field exercises in ecosystem restoration, and the technological integration in the monitoring of water bodies received high appreciation. Also, students using VR (virtual reality) simulations and other VR tools to self-immerse in 3D water-body simulations further enhanced interest levels. Students who used VR and field studies learned a broader, richer set of practical skills and theory, applied in real-world situations. They also learned more about the water conservation practice.

Figure 4: Multi-Metric analysis: interplay of student engagement and time investment in aquatic learning.

Figure 4 illustrates the correlation between five concrete learning activities, student metrics performance, and resource distribution, using student engagement relative to time spent on learning activities (in hours). Figure 4 – Graph 10 – Water sampling activity with average score engagement level & time spent" reveals a complex, non-arithmetic correlation between time spent on an activity and engagement level. Water sampling demonstrated a perceived engagement score of 4.8, suggesting a correlation in which students invest an average of 15 kg hours. In contrast, VR Simulations performed the most disengagingly under apathetic conditions. They scored lowest on all engagement metrics, resulting in a 0.2 score dip, which is in a correlated quadrant with low time investment. Notably, the decline in time, also described as 'time spent' perception, engagement phenomena, field research, and habitat restoration, depicts a situation where students' time perception is met with the engagement paradox. This portrait describes the allocation of resources rather than the value derived from an action. In the middle range, where time required has a high correlation with time expended, VR simulations show an impressive slack relating to attention and investment needed.

Student Perspectives of Integration of Sustainability in the Curriculum

The participants' reactions demonstrated the integration of the curriculum's sustainability concepts. A number of students appreciated the attention on practical aspects of the environmental issues together with the curriculum's specialization on sustainable management of water systems in terms of resource and biodiversity conservation. The case studies on restoration of ecosystems and on climate change and the sea helped students to understand critical issues of the sustainability and preservation of the oceans and the integration of global aquatic challenges. Many students suggested that the curriculum increased their understanding of sustainable use and management of marine resources and ecosystems, thereby equipping them for careers in the conservation and research of aquatic systems.

Table 1: Student response to sustainability and aquatic conservation curriculum.

Aspect	Rating (1-5)	Positive Feedback %	Number of Students (Estimated)
Sustainability Integration Success	4.6	85%	85
Curriculum Focus	4.7	88%	88
Impact on Biodiversity Awareness	4.6	83%	83
Case Studies on Ecosystem Restoration	4.5	80%	80
Climate Change Impact Awareness	4.7	87%	87
Broader Perspective on Sustainability	4.7	85%	85
Preparation for Future Careers	4.6	82%	82

Table 1 captures quantitative analysis of some of the comments offered by students with regard to the issues under the sustainability and aquatic conservation curriculum. Respondents are scored with ratings of 1 to 5. The summary captures the proportion of students willing to provide positive feedback (rated 4 or 5), as well as the total number of students estimated to give a positive reply. All elements have a similar focus of the curriculum, such as sustainability, which captures and documents the curriculum focus, and employment readiness, or predictive. This gives an overview of the input that students provide and the activities they undertake in the program.

Long-Term Application, Career Impact

The feedback gathered from discussions and the surveys conducted with the alumni points towards the inclusion of transdisciplinary integration in the curriculum, having a useful effect. It influenced the career pathways and professionally relevant knowledge of alumni with respect to aquatic biodiversity and sustainability. Alumni trained in environment-oriented research, policy, and conservation stated that the combination of disciplines, transdisciplinary integration, aided in the enhancement of their mental models and shifted their problem-solving strategies for real-life complex aquatic systems. Another prevalent issue, as stated by alumni, was their lack of ability to function in interdisciplinary teams. They incorporated policy, marine biology, and engineering to provide solutions to intricate problems in the conservation of water bodies and the sustaining of aquatic resources. This illustrates the enduring dimension of the curriculum content. Alumni are conditioned to resolve intricate interdisciplinary issues, Amal, gaining various aspects of learning to address world problems concerning the sustainability of the aquatic systems.

Table 2: The effect of interdisciplinary curriculum on the development of skills and career of graduates.

Category	Number of Graduates Reporting Impact	Percentage Reporting Impact (%)	Number of Graduates Not Reporting Impact
Career Choices	250	85%	45
Understanding of Aquatic Systems	230	80%	60
Application of Knowledge	220	77%	70
Interdisciplinary Skills	210	75%	80
Teamwork & Collaboration	200	70%	90
Long-Term Career Impact	240	84%	50

In Table 2, the results of the study concerning the impact of the interdisciplinary curriculum on the career and skill attainment of graduates are given. It captures the positive returns of graduates on various domains, including career pathways, understanding of aquatic systems, application of interdisciplinary parameters, collaboration, and influence on a sustained career. Further, the table illustrates the portion of graduates who attested to each impact and the number who did not receive these benefits. The data indicate that an integrated curriculum adequately prepares graduates to handle persistent global issues involving aquatic biodiversity and its sustainable use.

Conclusion

The integration of various disciplines in the curriculum enhanced understanding of aquatic biodiversity and sustainable aquatic services under tertiary education. Interdisciplinary curricula include and more successfully address all the environmental sciences barrier disciplines, marine environments, and legal studies, and critically appreciate the complex issues of ecosystems. The integration of field studies, virtual realities, and aquatic systems helped the learners translate their classroom knowledge to the field and experience enhanced problem-solving skills. Cross-divider learning, disciplines spanning different levels of aquatic biodiversity and advanced aquatic services, tertiary studies, and integrating all disciplines. The diploma's formulation of sustainable development allowed students to understand the value of preservation of the allocated water systems for the future. The career choices of graduate in aquatics research, conservation, and policy suggest, and their retention confirms, the effectiveness of this particular approach. These professionals, owing to the curriculum, are able to respond to the changes in the planet's aquatic systems due to their training on the critical issues of the conservation of aquatic biodiversity and sustainable use of the resources. The need to enhance such interdisciplinary programs at the tertiary level, in light of the increasing threats, is imperative. These programs will prepare the upcoming generations of researchers and policy makers with new approaches for the sustainable custodianship of aquatic biodiversity.

References

Abdolabade, R.K., Seyedan, A., Smaili, H. and Zendedel, M. 2017. Curriculum Students with Special Needs, *International Academic Journal of Social Sciences*, *4*(2), pp. 54–57.

Ajiga, D.I., Hamza, O., Eweje, A., Kokogho, E. and Odio, P.E., 2025. Developing interdisciplinary curriculum models for sustainability in higher education: a focus on critical thinking and problem solving. *J. Public Adm. Soc. Welf. Res*, *10*, pp.87-102.

Anapana, G., Donkada, S., Surarapu, N. and Rathnamma, V., 2025. Multidisciplinary Integration in Zoology Education: Bridging Biological, Computational, and Environmental Sciences. *Uttar Pradesh Journal of Zoology*, *46*(8), pp.317-331. https://dx.doi.org/10.56557/upjoz/2025/v46i84916

Annan-Diab, F. and Molinari, C., 2017. Interdisciplinarity: Practical approach to advancing education for sustainability and for the Sustainable Development Goals. *The International Journal of Management Education*, *15*(2), pp.73-83. https://doi.org/10.1016/j.ijme.2017.03.006

Bacon, C.M., Mulvaney, D., Ball, T.B., Melanie DuPuis, E., Gliessman, S.R., Lipschutz, R.D. and Shakouri, A., 2011. The creation of an integrated sustainability curriculum and student praxis projects. *International Journal of Sustainability in Higher Education*, *12*(2), pp.193-208. https://doi.org/10.1108/14676371111118237

Consorte-McCrea, A. and Newing, H., 2015. Creating spaces for interdisciplinary exchange in higher education: A case study. *Local Economy*, *30*(3), pp.265-279. https://doi.org/10.1177/0269094215578219

De Beer, R. and Msezane, S.B., 2024. The Influence of Environmental Education on Nature Conservation in South Africa. *International Online*

Journal of Education & Teaching, *11*(3).

Gaard, G.C., Blades, J. and Wright, M., 2017. Assessing sustainability curriculum: From transmissive to transformative approaches. *International Journal of Sustainability in Higher Education*, *18*(7), pp.1263-1278. https://doi.org/10.1108/IJSHE-11-2015-0186

Goodale, T.A., 2020. Factors that influence curricular adoption in a sustainability focused marine science professional development for in-service teachers. *Journal of Education for Sustainable Development*, *14*(1), pp.5-19. https://doi.org/10.1177/0973408220934645

Miranda, J., Maricato, R., Nova, J.V., Baptista, J.M., Monteiro, J.L., Freitas, N., Gonçalves, O., Vale, V. and Azul, A.M., 2016. Interdisciplinary and participatory research at early childhood to biodiversity education and sustainable development. In *Biodiversity and Education for Sustainable Development* (pp. 265-285). Cham: Springer International Publishing.

Mohameed, H., Muthazhagu, M., Punitha, K., Anvarovna, A.S., Rajendren, D.J. and Sachdeva, L. 2025. ‘Interdisciplinary Information Systems for Health and Education Libraries’, *Indian Journal of Information Sources and Services*, *15*(2), pp. 11–15. https://doi.org/10.51983/ijiss-2025.IJISS.15.2.02

Mokski, E., Leal Filho, W., Sehnem, S. and Andrade Guerra, J.B.S.O.D., 2023. Education for sustainable development in higher education institutions: an approach for effective interdisciplinarity. *International Journal of Sustainability in Higher Education*, *24*(1), pp.96-117. https://doi.org/10.1108/IJSHE-07-2021-0306

Nasirpour, M., Mohammadian, T., Soltani, M., Mirzagar, S. and Houshmand, H., 2024. Effect of Different Marine Probiotics Individual and with B-Glucan on Digestive Enzymes Activity, and Intestine Flora of Acanthopagrus Arabicus. *Journal of Animal Environment*, *16*(3), pp.89-98. https://doi.org/10.22034/AEJ.2023.415050.3029

Oliveira, A.P., Paramés, A., Bajanca, A. and Martinez-Perez, C., 2025. Higher Education Students’ Biodiversity Knowledge. *Education Sciences*, *15*(4), p.499. https://doi.org/10.3390/educsci15040499

Parker, J., 2010. Competencies for interdisciplinarity in higher education. *International Journal of Sustainability in Higher Education*, *11*(4), pp.325-338. https://doi.org/10.1108/14676371011077559

Podgórska, M. and Zdonek, I., 2024. Interdisciplinary collaboration in higher education towards sustainable development. *Sustainable Development*, *32*(3), pp.2085-2103. https://doi.org/10.1002/sd.2765

Scoarize, M.M.R., Contieri, B.B., Delanira-Santos, D., Zanco, B.F. and Benedito, E., 2022. An interdisciplinary approach to address aquatic environmental issues with young students from Brazil. *International Research in Geographical and Environmental Education*, *31*(1), pp.38-52. https://doi.org/10.1080/10382046.2021.1943220

Sen, V. and Malhotra, N., 2025. A Critical Analysis of the Education for Sustainable Development. *International Journal of SDG's Prospects and Breakthroughs*, pp.22-27.

Simanjuntak, M.B., Rafli, Z. and Utami, S.R., 2024. Enhancing maritime education for ocean sustainability: A multidisciplinary approach. In *BIO Web of Conferences* (Vol. 106, p. 02006). EDP Sciences. https://doi.org/10.1051/bioconf/202410602006

Smitha, C., Mani, S. and Arumugam, A. 2025. An Empirical Study on How IT Companies in Bangalore Collaborate with Educational Institutions to Develop Sustainability-Focused Curriculum on Employee Training and Development for Future IT Professionals, *Indian Journal of Information Sources and Services*, *15*(2), pp. 391–399. https://doi.org/10.51983/ijiss-2025.IJISS.15.2.47

Spelt, E.J., Biemans, H.J., Tobi, H., Luning, P.A. and Mulder, M., 2009. Teaching and learning in interdisciplinary higher education: A systematic review. *Educational psychology review*, *21*(4), pp.365-378.

Strachan, S., Logan, L., Willison, D., Bain, R., Roberts, J., Mitchell, I. and Yarr, R., 2023. Reflections on developing a collaborative multi-disciplinary approach to embedding education for sustainable development into higher education curricula. *Emerald Open Research*, *1*(9). https://doi.org/10.1108/EOR-09-2023-0007

Tupas, F.P., Matsuura, T. and Muryuno, M., 2025. Fostering Marine Biodiversity and *Social Impact via Creative Outputs in Sustainable Community Outreach Programs.* https://doi.org/10.20944/preprints202509.0112.v1

Verma, A. and Mehta, N., 2024. The Role of IoT in Modern Electrical Systems: An Interdisciplinary Approach in the Periodic Series. *Smart Grid Integration*, pp.13-18.

Vincent, S. and Focht, W., 2011. Interdisciplinary environmental education: elements of field identity and curriculum design. *Journal of Environmental Studies and Sciences*, *1*(1), pp.14-35.