



Biomimicry Potentials for Sustainable Student Financing in Higher Education

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Abstract. The high cost of higher education globally has become a major challenge to achieving the United Nations Sustainable Development Goal Four (SDG 4), which aims to ensure an inclusive and equitable quality education. Overcoming this barrier requires introducing a sustainable student financing model that can bridge the wide gap between the various societal classes, especially in developing countries like South Africa. Biomimicry, the study of natural models, systems, strategies and elements to sustainably solve complex human challenges, offers an innovative framework for addressing the financial challenges faced by students in higher education. Hence, this paper explores the potential of biomimicry to foster sustainable and resilient financing mechanisms, drawing parallels from nature's inherent efficiency, adaptability, and self-sustenance. Drawing inspiration from the symbiotic relationships that exist in biotic and abiotic entities in nature, a financing model that promotes mutual benefit, equity, and inclusivity can be envisioned. This paper provides examples of nature-inspired models around decentralisation, efficient and effective resource allocation, cyclical processes, collaboration and symbiosis, and resilience, which can serve as a potent wellspring for sustainably revolutionising higher education student financing. Lessons drawn from these natural models offer a sustainable student finance framework that can enhance resilience and equity, ensuring that financial support reaches a broader and more diverse student population. Conclusively, a mutually beneficial, equitable, and sustainable higher educational landscape for the present and future generations can be cultivated by drawing inspiration from nature's wisdom. It is recommended that multi-stakeholder collaboration and cooperation be embraced to ensure a successful outcome that will subsequently drive the achievement of SDG 4.

Keywords: Biomimicry; Higher Education; Nature; South Africa; Student Finance; Sustainable Development Goal 4.

1 Introduction

Education plays a crucial role in promoting civilisation and enhancing the economic well-being of the people. It is the cornerstone of societal advancement, playing a pivotal role in the development of both developing and developed nations. Attesting to the significance of education, the Millennium Development Goal (MDG) Two and the

Sustainable Development Goal (SDG) Four of the United Nations (UN) are both aimed at achieving universal primary education and inclusive and equitable quality education, respectively. Several scholars opined that to achieve sustainable development, the role of education cannot be overemphasised (Diemer et al., 2020; Abera, 2023). While the core objectives of education are to impart knowledge, foster critical thinking, and cultivate skills, the specific roles and impacts of education vary significantly considering the contexts of World Development Indicators (WDI) by the World Bank. Education is fundamentally transformative in developing nations, serving as a powerful tool for poverty alleviation and socio-economic mobility. Access to quality education in these regions can break the cycle of poverty by equipping individuals with the skills needed to secure better employment opportunities and improve their quality of life. Primary and secondary education lay the groundwork for literacy and numeracy, essential for personal and community development. Globally, several countries have enacted laws, policies, and legislations that make it mandatory for every child of school age to have access to uninterrupted basic education. Basic education in developed countries such as the United Kingdom is free and supported by massive budgetary allocation by the government. In Nigeria, the Universal Basic Education (UBE) scheme is a government institution with the fundamental principle that every child should be afforded an unbroken nine years of qualitative basic education (Okujagu, 2013). Similarly, the right to basic education is enshrined in the Bill of Rights as contained in the South African constitution, thereby highlighting the importance of education (Ndzimbomvu et al., 2021). While the navigation of basic primary and secondary education has been fairly successful, tertiary education remains an uphill task due to its enormous financial implications and other impeding factors.

Higher education fosters economic development by creating a skilled workforce that drives innovation, productivity and employment opportunities. Programmes offered by universities and technical and vocational education and training (TVET) colleges are particularly crucial, as they provide practical skills and curricula tailored to local and national economies at par with continental and global needs. The focus often includes expanding access to education, improving the quality of educational institutions, and addressing gender disparities to ensure inclusive and equitable education for all. Hence, higher education institutions (HEIs) are crucial in driving economic development and advancing social equity (Blankenberger & Williams, 2020). Due to socio-economic factors and several other reasons, student financing requires special attention from the government and other relevant stakeholders. Hence, this paper aims to present the potential of biomimicry to foster and propel sustainable student financing in the higher education sector. To achieve the aim of the study, an extant review of relevant literature on student financing mechanisms and the influence of biomimicry in reinventing student financing in the higher education sphere. A detailed analysis and presentation of the potential capabilities of biomimicry towards ensuring sustainable student financing in higher education was done and presented. The paper's final section encapsulates the conclusions drawn alongside the recommendations highlighted to aid the adoption and implementation of biomimicry concepts for sustainable student financing in higher education.

2 Understanding Sustainable Student Financing

With the escalating costs of higher education, student financing is a critical issue globally. To effectively address this challenge, sustainable student financing models must be developed to ensure that students (especially the vulnerable and poor ones) can access education without incurring debilitating debt. Sustainable financing encompasses affordability, accessibility, and financial stability for students, institutions, and governments. For example, the traditional models of student loans are increasingly unsustainable. In the United States alone, student debt has grown from almost \$1.2 trillion in May 2013 to \$1.4 trillion around 2016 and over a whopping \$1.7 trillion in 2024, burdening graduates and impeding their economic contributions (Chopra, 2013; Ciciora, 2016; Amon, 2024; Hanson, 2024). Similarly, rising tuition fees and inadequate financial aid create significant barriers to higher education in many parts of the world. Also, stringent and unfavourable requisite conditions before prospective students can access student financial aid/loan pose a great barrier as well. Sustainable student financing, therefore, requires a rethinking of how education is funded, moving away from debt-dependent models towards more equitable and supportive systems.

One promising approach is the implementation of income-share agreements (ISAs). It is an education financing tool through which students pledge a percentage of their future income share for upfront funding of their post-secondary education (Oei & Ring, 2015; Taylor & McBeth, 2020). According to Zaber and Steiner (2021), ISAs are contracts between funders and students where the students receive financial support for their post-secondary education with the agreement to repay using a percentage of their future salary once they secure a job that enables them to make these payments. With ISAs, students are allowed to pay a percentage of their future income for a set period after graduation instead of borrowing a fixed amount upfront. The National Student Financial Aid Scheme (NSFAS), established in South Africa under the National Student Financial Aid Scheme (Act 56 of 1999), is an example of the ISA approach. This approach aligns the cost of education with graduates' ability to pay, reducing financial stress and default rates. Moreover, ISAs encourage educational institutions to invest in their students' employability, fostering a mutually beneficial relationship.

Scholarship programmes, particularly those that target underserved communities and groups of students, are another vital component of sustainable student financing in higher education. These programmes alleviate financial burdens and promote diversity and inclusion within higher education. Governments and private sector partners have the opportunity to collaborate to expand scholarship opportunities, ensuring that financial aid is accessible to those who need it most. In South Africa, corporate organisations and government entities have made the provision of scholarships an integral part of their Corporate Social Responsibility (CSR). Various scholarships target Indigenous students or those who hailed from the community hosting the organisation or corporation. Additionally, performance-based scholarships are another category which can incentivise academic excellence and timely graduation, contributing to the overall efficiency of the higher education sector. A few examples of these scholarships in South Africa are the SANRAL scholarship, TETA bursary, Thuthuka

Bursary, Masakh'iSizwe bursary, Vodacom bursary, Hollywood Foundation bursary, Shoprite bursary, Margaret McNamara Education Grant's bursary, Sappi bursary, South African Reserve Bank bursary, Sasol Mining bursary, Investec CSI Bursary programme, and KPMG bursary among numerous others.

In the case of South Africa and many other countries worldwide, public funding remains essential in sustainable student financing of higher education (Viaene & Zilcha, 2013). Governments prioritising higher education in their budgets and recognising it as a public good is imperative and has far-reaching societal benefits. Progressive taxation and education levies can generate the necessary resources, ensuring that higher education institutions are adequately funded and minimising over-reliance on student fees (Liefner, 2003). Moreover, public funding that is designed to support students and HEIs creates a balanced and resilient education system. Work-study programmes also offer a sustainable financing solution by integrating employment with higher education. These programmes provide students with part-time jobs and internships, allowing them to earn money and gain valuable work experience while increasing their ability to pay for their education (Baum, 2023). This financing model reduces students' reliance on loans and enhances their employability upon graduation. HEIs have the opportunity to partner with local businesses, organisations, corporate entities, and government agencies to expand work-study opportunities and align higher educational outcomes with industry/labour market demands. Financial literacy education is another critical element of a sustainable student financing mechanism (Cull & Whitton, 2011). Excessive borrowing can be prevented, and long-term financial stability can be promoted when students are equipped with the knowledge and skills required to manage their finances effectively. Integrating financial literacy courses into the curricula of HEIs by offering workshops and resources to help students make informed decisions about their education and finances can foster sustainable student financing (Widdowson & Hailwood, 2007).

Sustainable student financing in higher education requires a multifaceted approach that balances immediate financial needs with long-term economic stability. By diversifying funding sources, promoting equitable access, and investing in financial literacy, a system that supports students without burdening them with unsustainable debt can be created. This holistic approach benefits individual students and strengthens the overall higher education system, fostering a more educated, productive, and equitable society. Conclusively, the pursuit of sustainable student financing is essential for ensuring that higher education remains accessible and beneficial for all. It requires innovative solutions, collaborative efforts, and a commitment to prioritising education as a vital public good. While biomimicry has been described as a novel and rich source of inspiration for developing sustainable solutions to human challenges, it can be consulted in the area of student financing in higher education. By learning from and emulating natural systems, HEIs and relevant stakeholders can create adaptive, circular, decentralised, and collaborative financial models that alleviate the financial pressures on students and promote long-term resilience and equity in the higher education sector. By embracing the principles of biomimicry, which have enabled natural organisms to thrive over the years, the way to a more inclusive and sustainable future can be paved in higher education.

3 Biomimicry-enabled Pathways for Sustainable Student Financing

Biomimicry, the practice of emulating nature's forms, processes, strategies and designs to solve human challenges sustainably, offers a plethora of innovative solutions for various fields such as aviation, medical and health sciences, engineering, military, sports and leisure, including sustainable student financing in higher education among numerous others. This is because natural organisms have been able to effectively and efficiently master, adapt, reinvent, manage, and evolve in their many years of existence. By observing nature's unique attributes (known as the biomimicry life principles, life principles, or nature principles), human beings are presented with vast deposits of innovative ideas and solutions to solve various challenges sustainably. Nature's resilience and adaptability are key to its survival and flourishing. For example, forests often show remarkable resilience after wildfires. Lodgepole pine in North America has cones that only release seeds in response to the intense heat of a fire (Perry & Lotan, 1979; Teste & Lieffers, 2011). This adaptation allows the species to quickly regenerate in the nutrient-rich, ash-covered soil left behind by the fire. Over time, new saplings grow, and the forest can return to its former state or even thrive with greater biodiversity. Similarly, many animal species have adapted to urban environments. For instance, peregrine falcons have successfully adapted to living in cities, nesting on tall buildings that mimic their natural cliffside nesting sites (Caballero et al., 2016; Goode, 2020). They hunt urban prey like pigeons and have adapted their hunting strategies to the urban landscape. This adaptability has allowed their populations to recover in areas where they were previously declining. These traits can inform the design of adaptable and resilient student financing models. By observing and applying nature's principles, a more efficient, resilient, and sustainable student financing concept for higher education can be developed. A careful and in-depth analysis of the natural ecosystem revealed few major nature-inspired potentials for sustainable student financing in higher education. Drawing lessons from different entities in nature, some of the biomimicry potentials for sustainable student financing include decentralised financial networks, adaptive funding mechanisms, collaborative and symbiotic relationships, dynamic equilibrium, circular economy, long-term vision, self-regulating systems, resilience through redundancy, distributed resource allocation, collective intelligence, and mutual aid and support among others

3.1 Decentralised Financial Networks: Lessons from Mycelium

Mycelium networks distribute nutrients efficiently through symbiotic relationships with plants. This decentralised approach can inspire financial models with diversified and interconnected funding sources. Instead of relying solely on traditional loans and government grants, a mycelium-inspired system could integrate various funding streams, including community-based micro-financing, alumni contributions, crowdfunding, and corporate partnerships. Such a network enhances resilience by reducing dependence on any single funding source, thereby mitigating risks associated with economic fluctuations.

3.2 Adaptive Funding Mechanisms: Mimicking Migratory Patterns

Migratory birds exhibit remarkable adaptability, adjusting their routes and behaviours in response to environmental changes. Similarly, adaptive funding mechanisms can be designed to respond dynamically to students' evolving needs. For instance, income share agreements (ISAs), where students repay a percentage of their future income, align repayment terms with graduates' financial situations. This model mimics the flexibility of migratory patterns, ensuring that repayment is sustainable and adjusts to individual economic circumstances.

3.3 Collaborative and Symbiotic Relationships: Coral Reefs as a Model

Coral reefs thrive through intricate symbiotic relationships among various marine organisms. Translating this to student financing, collaborative efforts between educational institutions, governments, private sectors, and communities can create a resilient financial ecosystem. By pooling resources and sharing responsibilities, these stakeholders can offer scholarships, grants, and work-study programmes that support students more holistically. This collaborative model mirrors the interdependence seen in coral reefs, fostering a supportive and sustainable financial environment. Also, universities could partner with local businesses to create internship opportunities that provide students with financial support and practical experience. Similarly, alumni networks could offer mentorship and funding opportunities, creating a community-based support system that mirrors the interconnected and mutually beneficial relationships in coral reefs.

3.4 Dynamic Equilibrium: The Wisdom of Ecosystem Self-Regulation

Ecosystems maintain dynamic equilibrium through feedback loops and self-regulation. Student financing systems can adopt similar principles by incorporating real-time data and analytics to monitor financial health and make adjustments. Predictive analytics can identify potential financial stress points, allowing for pre-emptive interventions. For example, universities can offer targeted financial literacy programmes or emergency grants to students showing early signs of economic distress, ensuring the system remains balanced and resilient. Considering that universities in South Africa enjoy incentives, subsidies or grants upon timely completion of their students in both undergraduate and postgraduate programmes, tuition waivers or discounts can therefore be granted by the university to needy and academically outstanding learners which will be recouped through the government grants. An example can be found in the South African HEIs charging no fees for their postgraduate programmes which attract high subscriptions of prospective students and consequently a higher return on investment to the universities through the government subsidies to be received upon their timely completion.

3.5 Circular Economy: Waste Reduction and Resource Efficiency

Nature operates on principles of a circular economy, where waste is minimised, and resources are efficiently utilised. Applying this to student financing, institutions can implement policies that promote resource efficiency and reduce financial waste. For instance, textbook-sharing programmes, open educational resources, and technology-driven learning platforms can significantly reduce educational costs, making higher education more accessible and sustainable.

3.6 Long-Term Vision: Emulating the Lifecycles of Trees

Trees invest in long-term growth and sustainability through deep root systems and gradual expansion. Similarly, sustainable student financing requires a long-term vision. Establishing endowments and investment funds dedicated to supporting future generations of students can provide a stable financial foundation. Just as trees contributed to the ecosystem over centuries, these financial mechanisms ensure enduring support for education.

3.7 Self-Regulating Systems: Ecosystem Feedback Loops

Natural ecosystems maintain balance through feedback loops and self-regulating mechanisms. For instance, predator-prey dynamics help regulate population sizes and resource availability. In student financing, implementing feedback mechanisms can ensure the system remains balanced and responsive to changing needs. Real-time data analytics can monitor students' financial health and identify emerging issues, allowing for timely interventions. For example, universities could use predictive analytics to identify students at risk of financial distress and provide targeted support, such as emergency grants or financial counselling, to prevent crises before they escalate.

3.8 Resilience Through Redundancy: The Robustness of Mangrove Forests

Mangrove forests are resilient to harsh environmental conditions due to their extensive root systems and redundancy. If one root is damaged, others compensate, ensuring the stability of the entire ecosystem. Similarly, redundancy in student financing can enhance resilience. Multiple funding sources, such as scholarships, grants, work-study programmes, and income share agreements (ISAs), can provide a safety net for students. If one funding source becomes unavailable, others can fill the gap, ensuring that students continue to receive the financial support they need.

3.9 Distributed Resource Allocation: The Wisdom of Leaf Venation

Leaf venation patterns demonstrate efficient resource distribution. Leaves have a network of veins that distribute water and nutrients evenly, ensuring that all parts of the leaf receive adequate resources. This efficient and equitable distribution system can inspire student financing models that ensure funds are allocated where they are most needed. A distributed resource allocation system in higher education could involve dynamic, need-based funding distribution, where resources are continuously assessed

and redirected based on real-time data. This ensures that students facing the greatest financial challenges receive the support they need, like how leaves distribute nutrients to their most critical areas.

3.10 Collective Intelligence: Ant Colonies

Ant colonies operate remarkably efficiently through collective intelligence, where individuals work together for the common good. Ants communicate and coordinate through pheromone trails, ensuring resources are allocated where needed. In student financing, this principle can inspire systems that use data and technology to enhance collaboration and resource allocation. Real-time data analytics can monitor students' financial needs and academic progress, enabling institutions to distribute funds more effectively. For example, predictive models can identify students at risk of economic distress, allowing for timely interventions such as emergency grants or financial counselling. This ensures that financial resources are directed to where they can have the most significant impact.

3.11 Mutual Aid and Support: Bee Hives

Bee hives thrive on the principle of mutual aid, with bees working together to ensure the survival and productivity of the colony. Each bee has a role, from foraging for nectar to protecting the hive, and their collective efforts sustain the entire community. This model can be translated into student financing through cooperative funding mechanisms. For example, peer-to-peer lending platforms can allow students to support each other financially, with alumni and community members also contributing. This creates a sense of shared responsibility and community, fostering an environment where everyone works together to ensure educational accessibility and success.

4 Conclusion and Recommendations

Nature operates through systems that are inherently sustainable, adaptable, and resource-efficient. These characteristics can be harnessed to address the pressing challenge of student financing in higher education. The decentralised networks found in mycelium, the efficient resource distribution of leaf venation, the symbiotic relationships in coral reefs, the resilience through redundancy seen in mangrove forests, and the adaptive feedback loops of ecosystems, among numerous other nature-inspired strategies all provide blueprints for creating robust financial systems. By adopting the decentralised approach of mycelium networks, student financing can diversify its funding sources, reducing dependency on any single source and enhancing overall system resilience. The efficiency and equitable resource distribution of leaf venation can inspire need-based financial aid systems that dynamically allocate funds to students based on real-time financial needs, minimising waste and maximising impact. The collaborative symbiosis of coral reefs can be mirrored in partnerships among universities, governments, private sectors, and non-profit organisations, creating a support network that pools resources and shares responsibilities. The resilience prin-

principles of mangrove forests can be translated into student financing through multiple funding sources, such as scholarships, grants, work-study programmes, and income share agreements (ISAs), ensuring that if one source becomes unavailable, others can fill the gap. Ecosystem feedback loops demonstrate the importance of adaptive and responsive systems. In student financing, real-time data analytics can monitor financial health and academic progress, enabling timely interventions and optimising resource allocation. This ensures the financial support system remains balanced and responsive to students' evolving needs.

It is recommended that students' financial and academic status is monitored and evaluated to provide timely interventions, such as emergency grants or financial counselling, ensuring that resources are used effectively. Also, establishing a diversified portfolio of financial resources, including scholarships, grants, work-study programmes, and ISAs, is imperative to provide continuous support even if one source is compromised. More importantly, fostering partnerships among educational institutions, governments, businesses, and non-profit organisations to establish programmes like paid internships, mentorship networks, and community-funded scholarships to create a robust support system should be encouraged. By integrating the principles of biomimicry into student financing, systems that are sustainable, efficient, equitable, and resilient can be created. Nature's wisdom, honed over billions of years, offers a treasure trove of strategies for addressing human challenges. Embracing these lessons can lead to a transformative shift in how higher education is financed, ensuring that all students can pursue their academic goals without the burden of financial uncertainty. Through the innovative application of biomimicry, a future where education is accessible, sustainable, and supportive of every student's potential can be built.

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