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Cultivating practical skills among students through creative and innovative pedagogical approaches: A case study of the Foundation Students in a South African University

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ABSTRACT

In the 21st century, classroom pedagogical approaches must evolve to equip students with the creative and critical thinking skills essential for both academic and professional development. This study explored the transformative impact of creativity and innovative interdisciplinary teaching strategies on students' practical understanding of foundational science education in higher education. A comprehensive investigation examined how integrating biological modelling and web development in scientific mini projects improves engagement and knowledge retention across the two disciplines. This study followed constructivist and inquiry-based learning frameworks and implemented a dual-faceted pedagogical approach: (1) using modelling to simulate eukaryotic and prokaryotic cells to clarify their differences and dynamic biological processes, such as facilitated diffusion; and (2) developing interactive websites in Information Technology, allowing 2024 Science Foundation students to present, document, and reflect on their scientific explorations. Quantitative and qualitative data collected from evaluations of submitted cell structure models, created websites, and student reflections revealed significant improvements in students' abilities to visualise abstract biological concepts and apply computational thinking. These websites served not only as learning tools but also as assessment artifacts, fostering digital literacy alongside scientific inquiry. Students reported increased motivation, with 92% stating that integrating technology made learning more relevant and enjoyable. Moreover, this cross-disciplinary approach encouraged collaborative learning and developed transferable skills critical to academic and professional success. This advocates a reimagined foundational curriculum that is rich in content and experience-driven, technologically integrated, and aligned with the imperatives of 21st-century learning.

Keywords: Foundation, Biology, Information Technology, Creativity, Innovation, Collaboration, 21st Century

INTRODUCTION

In the 21st-century, the classroom pedagogical approaches should ultimately change to equip students with creative and critical thinking skills that are crucial for both academic and professional development. Teaching and learning should now incorporate creativity and innovation to align with the

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evolving teaching and learning strategies of the current era, which features diverse students in the classroom. Zitha et al. echoed that massification in higher education is one of the drivers that brings about diverse students in learning and teaching activities orchestrated within a single set of curricula and teaching styles.[1] Furthermore, Megbowon et al. emphasised the increased diversity of student characteristics in higher education institutions, highlighting the need for change in teaching pedagogies.[2] However, the biggest challenge is the use of the one-size-fits-all approach to learning and teaching activities.[3]

The results of this approach reveal serious shortcomings in students' ability to master certain concepts within the curriculum. Therefore, teaching and learning require the infusion of creative and innovative strategies to foster professional student engagement. Gamification is an innovative strategy that increases student motivation and improves their academic results.[4] In particular, innovative teaching is not just a modern pedagogical approach, but a requirement to improve the quality of education and prepare the next generation for the challenges of the 21st century.[5]

In the rapidly evolving landscape of 21st-century education, the ability to foster students' practical understanding has become a central concern for educators and policymakers. Traditional lecture-based teaching methods often fail to equip learners with the skills needed to navigate complex real-world challenges. As a result, there is a growing emphasis on adopting creative and innovative teaching practices that not only engage students but also promote deeper, more applicable learning. These pedagogical approaches, which range from project-based learning to the integration of digital technologies, are designed to cultivate critical thinking, collaboration, and adaptability.[6] On the other hand, Herodotou et al. propose a comprehensive framework for selecting innovative pedagogies, emphasising their grounding in educational theory, empirical effectiveness, and alignment with 21st-century competencies.[7]

Despite an increasing recognition of the importance of creativity and innovation in education, many classrooms continue to rely on traditional, teacher-centred instructional methods. These practices often limit students' ability to develop practical and transferable skills. Typically focused on memorisation and standardised testing, these conventional approaches do not adequately prepare learners for the dynamic and complex challenges of the modern world.

Research indicates that innovative teaching strategies, such as project-based learning, digital integration, and experiential learning, have significant potential to improve student engagement and deepen their understanding. However, the implementation of these methods remains inconsistent and underutilised.[8] Furthermore, many educators lack the training, resources, and institutional support necessary to adopt these innovative approaches effectively.[9]

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[1] Innocent Zitha, Georgina Mokganya, and Orifha Sinthumule, "Innovative Strategies for Fostering Student Engagement and Collaborative Learning among Extended Curriculum Programme Students," *Education Sciences* 13, no. 12 (2023): 1196.

[2] Funmilola Kemi Megbowon et al., "Challenges of First-Year Extended Curriculum Programme Students at a University in South Africa," *International Journal of Learning, Teaching and Educational Research* 22, no. 4 (2023): 178–94.

[3] Innocent Zitha, Mokgaetji Georgina Mokganya, and Tshidaho Manyage, "Integration of Blended Learning in the Advent of COVID-19: Online Learning Experiences of the Science Foundation Students," *Education Sciences* 13, no. 7 (July 11, 2023): 704, https://doi.org/10.3390/educsci13070704.

[4] Sriati Usman et al., "The Effect of Technological Pedagogical Content Knowledge (TPACK) on Rural Area Students' English Writing," *Journal of Language Teaching and Research* 15, no. 3 (May 8, 2024): 884–92, https://doi.org/10.17507/jltr.1503.21; Zitha, Mokganya, and Sinthumule, "Innovative Strategies for Fostering Student Engagement and Collaborative Learning among Extended Curriculum Programme Students."

[5] Albana Tahiri, "Implementing Innovations in Student-Centered Teaching," *Current Studies in Social Sciences* 135 (2021).

[6] Rene Pearce et al., "Project-Based Learning for Promotion of Entrepreneurial Education among First Level Science Students," *International Journal of Research in Business and Social Science (2147- 4478)* 14, no. 1 (February 25, 2025): 151–59, https://doi.org/10.20525/ijrbs.v14i1.3820; Charles Kivunja, "Innovative Pedagogies in Higher Education to Become Effective Teachers of 21st Century Skills: Unpacking the Learning and Innovations Skills Domain of the New Learning Paradigm," *International Journal of Higher Education* 3, no. 4 (September 9, 2014), https://doi.org/10.5430/ijhe.v3n4p37.

[7] Christothea Herodotou et al., "Innovative Pedagogies of the Future: An Evidence-Based Selection," in *Frontiers in Education*, vol. 4 (Frontiers Media SA, 2019), 113.

[8] D. Henriksen, P. Mishra, and P. Fisser, "Creativity and Technology in Education: An Uneasy Relationship.," *Teachers College Record* 123, no. 4 (2021): 1–28; G. Onyango and Y. Xiong, "Creative Teaching Strategies for 21st-Century Skills: A Review of Emerging Trends," *Journal of Educational Innovation* 18, no. 2 (2025): 45–60; Zitha, Mokganya, and Sinthumule, "Innovative Strategies for Fostering Student Engagement and Collaborative Learning among Extended Curriculum Programme Students."

[9] Senad Bećirović, "Challenges and Barriers for Effective Integration of Technologies into Teaching and Learning," in *Digital Pedagogy: The Use of Digital Technologies in Contemporary Education* (Springer, 2023), 123–33.

Bećirović also highlights both external and internal barriers to innovation, including insufficient professional development, limited access to technology, and a lack of administrative encouragement.[10] This disconnection between pedagogical theory and classroom practice presents a significant challenge.

With all this being highlighted, the purpose of this study is to explore how such innovative strategies can be used effectively employed to nurture students' understanding in ways that are both meaningful and practical. This study is grounded in theoretical frameworks, including constructivism, experiential learning, and the innovative pedagogies framework. This paper aims to provide a comprehensive analysis of how modern teaching practices can transform educational experiences and outcomes. This question: "How can creative and innovative teaching practices be systematically integrated into educational settings to nurture students' practical understanding in meaningful and sustainable ways?" will be addressed to achieve the purpose of this study.

LITERATURE REVIEW

The integration of creative and innovative teaching practices has become a focal point in educational research, particularly in preparing students for an unpredictable and rapidly changing world. Creativity is increasingly recognised as a core competency in 21st-century education, essential to foster adaptability, problem-solving, and lifelong learning.[11] However, despite widespread acknowledgement of its importance, the implementation of creativity in classroom settings remains inconsistent and often lacks a clear strategic framework. Henriksen et al. highlight the uneasy intersection between creativity and technology in education, noting that while both are emphasised in the curriculum, their practical integration in classrooms is under-researched and poorly understood.[12]

In the South African context, the need for innovative pedagogies is particularly urgent due to persistent inequalities, resource constraints, and a legacy of educational disparities. Although national policies, such as the White Paper on Education and Training and the Curriculum and Assessment Policy Statement (CAPS), advocate for learner-centred and skills-based approaches, their implementation has been uneven across provinces and schools.[13] Many educators face systemic challenges, including overcrowded classrooms, limited access to digital tools, and insufficient professional development opportunities.[14] These barriers hinder the adoption of creative teaching methods that could otherwise improve the engagement and practical understanding of learners.

The Fourth Industrial Revolution (4IR) in Education

The Fourth Industrial Revolution (4IR), which is characterised by the convergence of digital, physical, and biological technologies, including artificial intelligence, robotics, the Internet of Things (IoT), and big data, is indeed transforming education systems globally, and South Africa is no exception. In simpler terms, 4IR transforms the way knowledge is created, accessed, and applied. In education, this revolution demands a shift from traditional memorisation learning to more dynamic, skill-based approaches that prepare learners for a rapidly evolving digital economy. The South African government is integrating the 4IR into education, which is seen as both a strategic priority and a complex challenge. In this regard, the Department of Basic Education has introduced initiatives, such as the Coding and Robotics Curriculum for Grades R–9, aimed at equipping learners with foundational digital skills from an early age.[15] On the same note, universities and TVET colleges are aligning their programs with the demands of 4IR by incorporating data science, automation, and digital entrepreneurship into their curricula.[16]

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[10] Bećirović, "Challenges and Barriers for Effective Integration of Technologies into Teaching and Learning."
[11] Onyango and Xiong, "Creative Teaching Strategies for 21st-Century Skills: A Review of Emerging Trends."
[12] Henriksen, Mishra, and Fisser, "Creativity and Technology in Education: An Uneasy Relationship."
[13] Simphiwe Magagula, Ndwamato Mugovhani, and Sakhiseni Yende, "Challenges Encountered in the Enhancement and Optimal Teaching and Learning of the Creative Arts Subject in South Africa," *African Journal of Inter/Multidisciplinary Studies* 4, no. 1 (2022): 373–83, https://doi.org/10.51415/ajims.v4i1.1042.
[14] Mareli Stolp, "The Creative Practitioner in South African Higher Education: Practice and Scholarship in Conversation and Flux," *Acta Academica* 53, no. 1 (2021): 92–114.
[15] Department of Basic Education, *Draft Coding and Robotics Curriculum for Grades R–9* (Pretoria: DBE, 2021).
[16] Department of Higher Education and Training (DHET), *Strategic Plan 2020–2025* (Pretoria: DHET, 2020).

Challenges for the implementation of 4IR in education

There are ongoing debates over the mandatory nature of 4IR education; however, its implementation in education remains uneven, largely due to systemic inequalities.[17] Many schools, particularly in rural and under-resourced areas, lack the necessary infrastructure, including reliable electricity, internet access, and digital devices, to support technology-enhanced learning. Zitha et al. noted that challenges and predicaments, such as poor network connectivity, load shedding, and high data consumption rates during engagements, reinforce ineffective student participation.[18] In fact, these digital devices pose a threat to the goal of expanding 4IR education. In fact, if these are not addressed through targeted investment and inclusive policy design, the results will lead to educational disparities.[19]

Another predicament is that educators often lack the training and support needed to effectively integrate 4IR tools into their teaching. Professional development programs are essential to building teacher digital literacy and pedagogical confidence; yet such initiatives remain limited in scope and reach.[20] At least, the South African government has acknowledged these challenges through the establishment of the Presidential Commission on the Fourth Industrial Revolution, which aims to guide national strategy and foster cross-sector collaboration.[21] In this context, 4IR presents both a transformative opportunity and a pressing imperative for South African education. By embracing innovative pedagogies and addressing systemic barriers, the education system can better prepare learners for meaningful participation in the digital era and help build a knowledge-driven society. The Innovative Pedagogies Framework is a multidimensional approach to teaching that integrates emerging educational theories, technologies, and practices to foster 21st-century skills, including creativity, collaboration, critical thinking, and adaptability.

THEORETICAL FRAMEWORK

This research is underpinned by theoretical frameworks, including constructivism, experiential learning, and the innovative pedagogies framework. The simple truth is that these frameworks provide a foundation for designing meaningful, student-centred learning experiences.[22] The pedagogical strategies encompass the cultivation of skills such as digital literacy, problem-solving, and collaboration, which are essential for navigating modern challenges.[23] Furthermore, the pedagogies are selected based on research that demonstrates their impact on learning outcomes. For example, formative analytics and teach-back methods can be implemented because they have shown promise in enhancing student engagement and understanding. Additionally, Peterson et al. emphasise that innovative pedagogies must be adaptable and context-sensitive, meaning they should be scaffolded to an understandable pedagogy that combines separate teaching practices with broader educational goals for the 21st century.[24] Eventually, this approach supports systemic change and sustainable innovation in education.

Innovative pedagogies have emerged as essential tools for nurturing students' practical understanding in current education. These pedagogies are characterised by their alignment with 21st-century skills, integration of technology, and grounding in established educational theories such as constructivism and experiential learning. Innovative teaching must be interdisciplinary and contextually relevant, enabling learners to engage with real-world problems through creative approaches.[25] Similarly, Khine highlights the crucial role of teacher education in equipping educators

[17] Stolp, "The Creative Practitioner in South African Higher Education: Practice and Scholarship in Conversation and Flux."
[18] Zitha, Mokganya, and Manyage, "Integration of Blended Learning in the Advent of COVID-19: Online Learning Experiences of the Science Foundation Students."
[19] Stolp, "The Creative Practitioner in South African Higher Education: Practice and Scholarship in Conversation and Flux."
[20] Bećirović, "Challenges and Barriers for Effective Integration of Technologies into Teaching and Learning."
[21] Republic of South Africa (RSA), "Presidential Commission on the Fourth Industrial Revolution: Final Report." (Pretoria: Government Printing Works, 2020).
[22] Herodotou et al., "Innovative Pedagogies of the Future: An Evidence-Based Selection."
[23] Herodotou et al., "Innovative Pedagogies of the Future: An Evidence-Based Selection."
[24] Amelia Peterson et al., "Understanding Innovative Pedagogies: Key Themes to Analyse New Approaches to Teaching and Learning," *OECD Education Working Papers*, 2018.
[25] Carina Buckley and Maria Kukhareva, "Making Inspiration Mainstream: Innovative Pedagogies for the Real World," in *Applied Pedagogies for Higher Education: Real World Learning and Innovation across the Curriculum* (Springer, 2020), 269–97.

with the skills and mindset necessary to implement such pedagogies effectively.[26] A taxonomy-based approach proposed by Stensaker et al. further categorises pedagogical innovations, offering a structured lens through which educators can evaluate and adopt new teaching strategies.[27] Collectively, these perspectives outline the importance of designing the learning environment that is flexible, student-centred, and responsive to the evolving demands of education in the digital age.

METHODOLOGY

A mixed-methods approach was used to examine how integrating biological modelling and web development enhances student engagement and knowledge retention across the Life Sciences and Information Technology disciplines. First this first, the facilitator demonstrated the importance of collaboration in teamwork. This exercise highlighted its significance for the successful implementation of creativity and innovation in students' projects. In this juncture, the facilitator thoroughly explained the purpose of the exercise and requested permission to use the volunteer's picture for future purposes. The volunteers were then blindfolded and given the rope to use for constructing the heptagon. The methodology of the real projects was structured into two interconnected phases, each designed to foster active learning and cross-disciplinary thinking among 2024 Science Foundation students. The first phase comprised students' engagement in firsthand modelling activities to simulate both prokaryotic cells and some indispensable processes of the eukaryotic cells. These models were used to explore and differentiate cellular structures and dynamic biological processes, such as facilitated diffusion. This approach encouraged learners to construct meaningful understanding through the visualisation and manipulation of abstract biological concepts.

The second phase involved developing interactive websites within the Information Technology curriculum. Students used these platforms to present, document, and reflect on their scientific investigations. Each website served as a digital portfolio showcasing students' results from their scientific projects. In this study, the researchers employed a combination of quantitative and qualitative methods, including evaluating submitted cell structure models, analysing the developed websites, and reviewing student reflections. The findings demonstrated significant improvements in students' abilities to visualise complex biological systems and to effectively apply computational logic in their scientific presentations. The websites served as educational tools and assessment artefacts, highlighting the value of integrating technology into science education.

PRESENTATION OF FINDINGS AND DISCUSSION

This section presents the study's findings on integrating practical skills through innovative and dynamic pedagogical approaches. The research highlighted the importance of employing creative teaching methods that actively engage students, thereby facilitating the application of theoretical knowledge in real-world scenarios. Using a variety of instructional strategies, this study demonstrates the potential to improve students' practical competencies, better equipping them for success in their professional endeavours.

Role-play exercise

To kick-start students' collaborative research, a role-play exercise was conducted. The outcomes of the role-play activity reveal several important insights into student dynamics and the challenges of implementing collaborative, innovative teaching strategies. Firstly, the observation that students communicated only with their friends suggests a tendency toward social clustering, which can limit the diversity of perspectives and reduce the effectiveness of group-based learning (Figure 1). This behaviour aligns with findings from social learning theory, which emphasise the influence of peer relationships on engagement and participation.[28]

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[26] Myint Swe Khine, "Teacher Education and Innovative Pedagogies for the Future," in *Handbook of Research on Teacher Education: Pedagogical Innovations and Practices in the Middle East* (Springer, 2022), 3–11.

[27] Bjørn Stensaker, "Building Institutional Capacity for Student Competencies: An Organizational Perspective," *International Journal of Chinese Education* 10, no. 1 (January 1, 2021), https://doi.org/10.1177/22125868211006200.

[28] Albert Bandura, "Self-Efficacy: Toward a Unifying Theory of Behavioral Change.," *Psychological Review* 84, no. 2 (1977): 191.

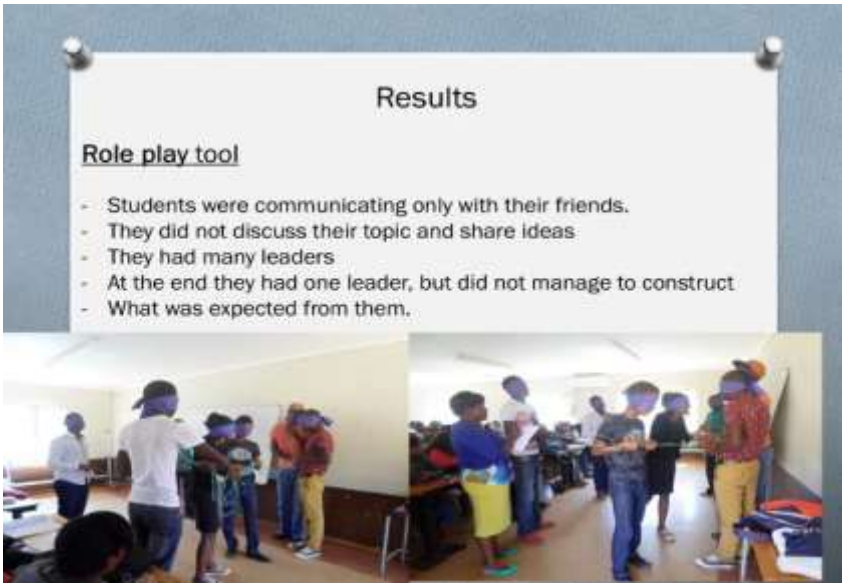

Figure 1: Outcomes of the role-play exercise

Secondly, the absence of focused discussions and idea-sharing indicates a deficiency in collaborative learning skills. Although role-play is designed to enhance creativity, critical thinking, and effective communication, its success relies on students' capacity to engage meaningfully with the assigned task. The presence of multiple leaders within groups may imply unclear role definitions or inadequate group management skills, leading to confusion and conflict rather than fostering productive collaboration.[29] Although a single leader eventually emerged, this development alone was insufficient to meet the anticipated outcomes. This shortcoming arose from a lack of shared understanding and inadequate coordination regarding the task's expectations. Therefore, it is crucial to scaffold group activities by providing clear instructions, defining roles, and implementing structured reflections to guide students toward achieving the intended learning outcomes.[30]

Phase 1 of the project (Creation of Biological Models)

One of the most compelling demonstrations of student creativity and innovation was observed in the construction of biological cell models using unconventional materials. In one example, students crafted a cell model using fabric, yarn, embroidery, and buttons. This approach deviated from traditional classroom materials, highlighting an elevated level of resourcefulness and artistic expression. The model contained representations of cellular components, such as the nucleus, mitochondria, and cell membrane, each crafted with distinct textures and colours. This not only reflected a solid understanding of biological structures but also enhanced the model's visual and tactile appeal (Figure 2).

The use of textiles and everyday materials aligns with the principles of constructivist learning theory, which shows that students actively construct knowledge through firsthand, meaningful experiences.[31] It also supports experiential learning theory, which holds that learning is most effective when students engage in concrete experiences followed by reflection and conceptualisation.[32] The process of designing and assembling the model encouraged collaborative problem-solving and cross-disciplinary thinking, integrating biological concepts with design and creativity.

[29] David W. Johnson and Roger T. Johnson, "An Educational Psychology Success Story: Social Interdependence Theory and Cooperative Learning," *Educational Researcher* 38, no. 5 (June 1, 2009): 365–79, https://doi.org/10.3102/0013189X09339057.
[30] Lev Vygotsky, *Mind in Society: The Development of Higher Psychological Processes* (Cambridge, MA: Harvard University Press, 1978).
[31] Vygotsky, *Mind in Society: The Development of Higher Psychological Processes*.
[32] D. A. Kolb, *Experiential Learning: Experience as the Source of Learning and Development* (Englewood Cliffs, NJ: Prentice-Hall, 1984).

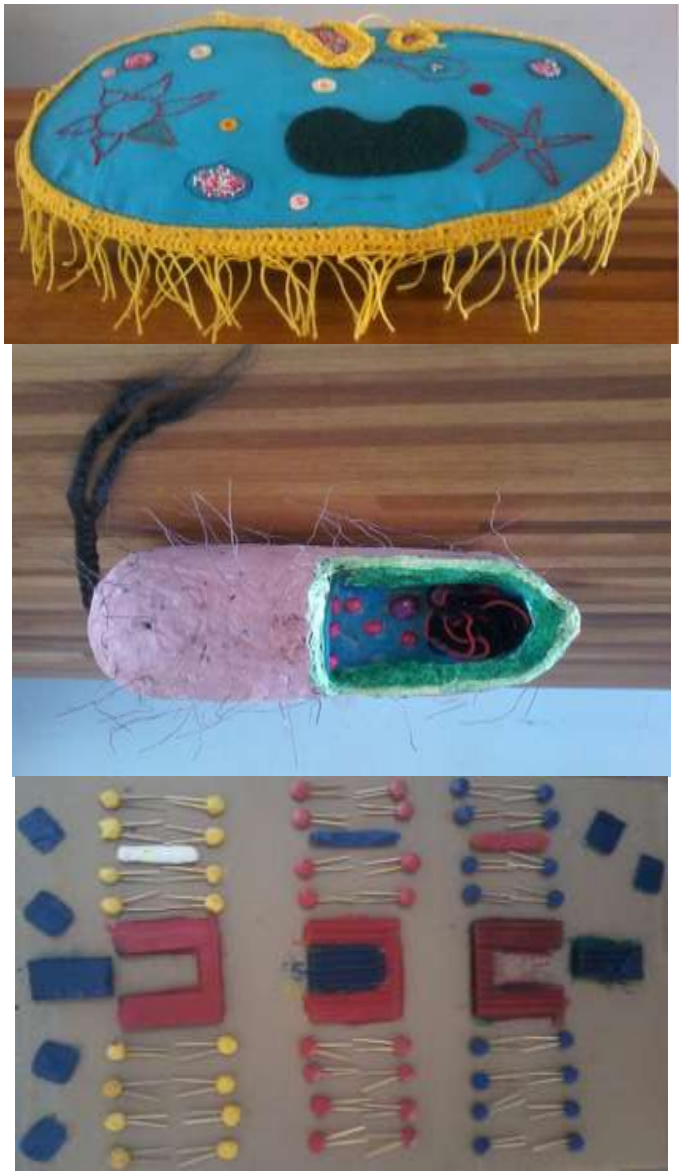

Figure 2: The crafted rod-shaped bacterial cell and the carrying mechanism of facilitated diffusion.

The educational methods not only provide practical experience but also encourage critical thinking, essential for fostering a deeper understanding of complex concepts. This finding aligns closely with established research on maker education and design thinking, which suggests that firsthand, project-based learning approaches can significantly improve student motivation, self-efficacy, and active engagement in science and technology subjects.[33] Furthermore, actively involving students in creating educational resources not only instils a sense of ownership over their learning but also enhances their commitment to the subject matter. This phenomenon is well-documented in student partnership models in higher education, where collaborative initiatives have been shown to strengthen students' learning experiences and outcomes.[34]

[33] A.I. Santos et al., "Maker Education and Creativity: A Systematic Review of Empirical Studies.," *International Journal of Educational Research Open.* 6 (2025).
[34] Katharine Hubbard et al., "Challenges and Opportunities for Early-Career Teaching-Focussed Academics in the Biosciences," *F1000Research* 4 (2015): 76.

For several million years, young people have learned how to adapt successfully by learning practical skills from their elders.[35] During the last few generations, they have become dependent on schools to acquire the information necessary to cope with their environment. Therefore, we must expect that creativity will be taught and practised in schools. Findings from Zitha et al. indicated that creative writers, musicians, and Nobel Prize-winning scientists had never praised their secondary schools for helping to develop their interest and expertise that led to their endeavours.[36] The only thing remembered from their high school days is one or two very influential teachers, but classroom activities were considered boring and oppressive.

Furthermore, Bamidele and Zitha emphasised that creativity can be defined as an original, valued, and implemented idea.[37] Creativity typically refers to the act of producing innovative ideas, approaches, or actions. On the other hand, Nekhubvi defined Innovation as a concept that requires critical thinking skills and persistence in finding viable solutions to a problem.[38] Essentially, innovation is the process of generating and applying creative ideas in a specific context. Enhancement of knowledge creation through relevant pedagogical competencies to better equip students with the knowledge and crucial skills they need for life.[39] So far, there is a serious lack of activities aimed at enhancing students' cognitive skills, including critical problem-solving techniques and the integration of tools that strengthen critical thinking.[40]

Creative and innovative teaching processes significantly rely on various pedagogical approaches, including active learning tools such as role-playing, radio shows, demonstrations, mind mapping/concept mapping, storytelling, games, brochure creation, and modelling. Meanwhile, Tahiri argues that innovative teaching is a process that relies on various pedagogical methods, including active learning techniques, language games, and technology, to foster exploration and creativity.[41] The developed models align with the goals of the Innovative Pedagogies Framework, which advocates learner-centred, creative, and contextually relevant teaching strategies.[42] They also demonstrate how affordable, accessible materials can support high-impact learning, particularly in resource-constrained educational environments.

Phase 2 (Website development)

In this part of the project, students were asked to create websites to highlight the findings of their scientific projects (Figure 3). The Brave Girls project exemplifies how creativity and innovation can be meaningfully integrated into science education through digital storytelling and interdisciplinary collaboration. By designing a website to present their research on the underutilised value of cow dung and cow urine, the students demonstrated not only scientific inquiry but also digital fluency and design thinking. This approach reflects the principles of innovative pedagogy, which encourages learners to engage with real-world problems using creative, student-driven methods.[43]

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[35] Orifha Sinthumule and Innocent Zitha, "From High-School Sciences to University Accounting in South Africa: How Prior Learning Affects Students' Success," *International Journal of Research in Business and Social Science (2147- 4478)* 13, no. 6 (October 14, 2024): 352–62, https://doi.org/10.20525/ijrbs.v13i6.3571.

[36] Innocent Zitha, Ditshego Masete, and Sarah Matsetela, "Using Artificial Intelligence Tools for Providing Feedback as A Strategic Response to Addressing Challenges in Students' Academic Writing," *E-Journal of Humanities, Arts and Social Sciences* 6, no. 7 (June 18, 2025): 1096–1111, https://doi.org/10.38159/ehass.20256712.

[37] Oluwaseun Peter Bamidele and Innocent Zitha, "Determining the Impact of Active Learning Strategies on Success Rate in Higher Education," *Journal of Education and Learning Technology* 6, no. 9 (September 29, 2025): 869–89, https://doi.org/10.38159/jelt.20256912.

[38] Vhutshilo Nekhubvi et al., "Effects of Students' Socioeconomic Status on Academic Performance: A Case of First-Year Students at a South African University," *International Journal of Business Ecosystem & Strategy (2687-2293)* 7, no. 2 (May 2, 2025): 414–21, https://doi.org/10.36096/ijbes.v7i2.758.

[39] Vesna Skrbinjek et al., "Enhancing Teachers' Creativity with an Innovative Training Model and Knowledge Management," *Education Sciences* 14, no. 12 (December 17, 2024): 1381, https://doi.org/10.3390/educsci14121381.

[40] B Japelj Pavešič, M Perošlja, and A Špegel Razbornik, "Lagging behind the Use of ICT for Teaching in Slovenian Primary and Secondary Schools," *Pedagoški Inštitut/Educational Research Institute Slovenia. Https://Www. Pei. Si/Wp-Content/Uploads/2021/01/Zaostajanje-Slovenije-v-Uporabi-IKT-Za-Poucevanje. Pdf. Accessed February* 8 (2020): 2022.

[41] Tahiri, "Implementing Innovations in Student-Centered Teaching."

[42] Herodotou et al., "Innovative Pedagogies of the Future: An Evidence-Based Selection."

[43] Herodotou et al., "Innovative Pedagogies of the Future: An Evidence-Based Selection."

The website's development served as an innovative platform for cross-disciplinary learning, effectively merging biological science with computer science. Through this project, students applied their knowledge of biology to investigate the diverse agricultural and medicinal uses of cow by-products, such as whey protein in nutritional supplements and the efficacy of cow manure as a natural fertiliser. At the same time, they used various web development tools and programming languages to design and communicate their findings in a visually engaging manner.

This integration of disciplines not only deepened students' understanding of biological concepts but also enhanced their technical skills in web development. By creating the website, they were able to display their research, fostering a sense of ownership in their learning process. This initiative aligns with the growing emphasis on computational thinking and digital creativity in K–12 education, where students are increasingly encouraged to view technology as a means of creation rather than mere consumption. As they navigate the intricacies of both biology and computer science, learners develop a more holistic skill set that prepares them for future challenges in an interconnected world.[44]

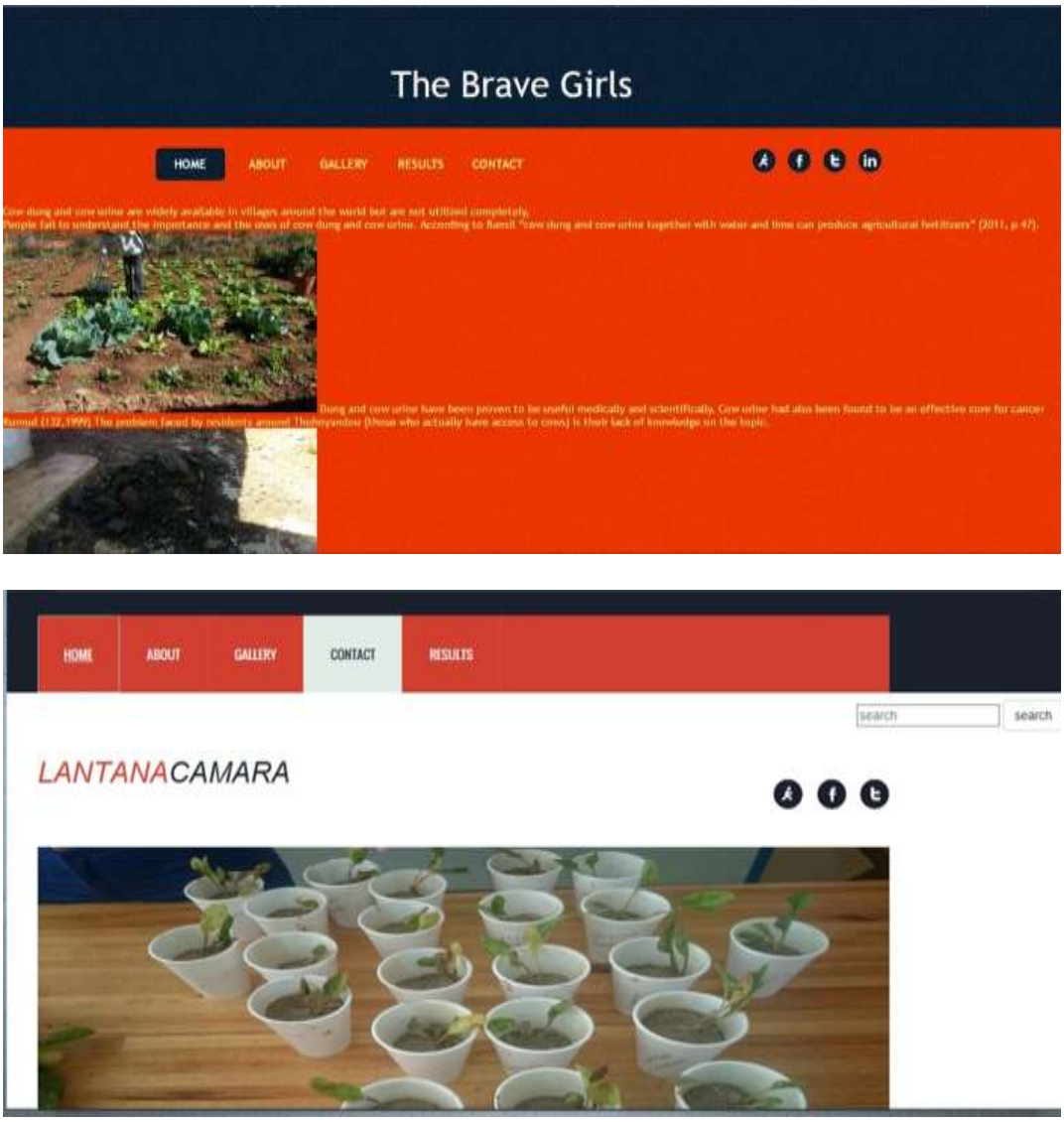

Figure 3: Students ' developed websites.

Moreover, the project illustrates the constructivist learning approach, where students actively construct knowledge through firsthand, collaborative experiences.[45] The digital format allowed them

[44] T.-C. Hsu, S.-C. Chang, and Y.-T. Hung, "Fostering Digital Creativity and Computational Thinking in K–12 Education: A Framework for Interdisciplinary Learning.," 2025.
[45] Vygotsky, *Mind in Society: The Development of Higher Psychological Processes*.

to curate content, design visual elements, and structure information in a way that was both informative and engaging. This process fostered critical thinking, problem-solving, and teamwork, acquired skills essential for thriving in the Fourth Industrial Revolution.

The project effectively addressed a significant knowledge gap in local communities by promoting awareness of sustainable agricultural practices in rural South Africa. By integrating scientific research and digital communication methodologies, the students not only enhanced their understanding but also made meaningful contributions to community education and empowerment. This initiative aligns with the broader educational objective of preparing learners to become innovative leaders and agents of change in their respective contexts.

RECOMMENDATIONS

The creation of the website has pioneered an innovative platform for cross-disciplinary learning, seamlessly merging biological and computer sciences. This initiative should be considered an opportunity for students to apply their theoretical knowledge of biology in real-world contexts, focusing on the diverse and often underappreciated uses of cow by-products in agriculture and medicine.

The students meticulously explored whey protein, a valuable by-product of cheese manufacturing known for its high nutritional content. They investigated its potential as a key ingredient in nutritional supplements, examining its benefits for muscle recovery, weight management, and overall health enhancement. This exploration included analysing the biochemical properties of whey protein and its digestibility, providing students with a comprehensive understanding of its importance in the health and fitness industry.

In addition, students conducted thorough research on cow manure, a natural fertiliser rich in nutrients. They assessed its effectiveness in promoting soil health and supporting sustainable farming practices. This involved studying the microbial communities in cow manure and their roles in nutrient cycling in agricultural ecosystems. By examining organic farming techniques and the environmental implications of fertiliser use, students gained insights into the critical balance between agricultural productivity and environmental stewardship.

Overall, this project not only deepened students' understanding of the interconnectedness of biological and computer sciences but also encouraged them to engage in critical thinking about sustainable practices and the real-world impacts of their research.

CONCLUSION

This study aimed to explore the transformative impact of creativity and innovative interdisciplinary teaching strategies on students' practical understanding of foundational science education in higher education. In the context of South Africa, these findings may highlight deeper systemic issues within the educational system that require attention. For instance, many educators currently have limited exposure to learner-centred pedagogies, which prioritise students' unique needs and experiences in the learning process. This approach is crucial to fostering an engaging and effective educational environment. However, many teachers remain firmly established in traditional teaching methods that do not adequately address individual learners.

Moreover, the prevalent issue of large class sizes significantly impedes educators' ability to provide personalised attention. When teachers are faced with overwhelming numbers of students, meaningful interactions such as individualised feedback and personalised guidance become challenging, ultimately affecting student engagement and comprehension.

Another critical area of concern is the training gap in collaborative learning methods. These methods are crucial in fostering teamwork, effective communication, and peer participation among learners. Effective classroom collaboration prepares students for real-world challenges, fostering critical thinking and problem-solving skills. Unfortunately, many educators lack the necessary training to foster such collaborative environments, resulting in missed opportunities for student development.

To effectively address these multifaceted challenges, it is essential not only to introduce innovative teaching tools and resources that foster active learning but also to invest heavily in educators' continuous professional development. This investment could take the form of comprehensive

workshops that focus on up-to-date teaching methodologies, mentoring programs that provide ongoing support, and access to resources that reinforce best practices in pedagogy.

Furthermore, institutional support is paramount. Schools and educational authorities must create an environment that actively encourages teachers to adopt new methodologies and collaborate. This can be achieved by fostering a culture of open communication that allows educators to share their successes, challenges, and strategies to improve the learning experience. By prioritising these efforts, we can significantly improve the educational landscape for all students in South Africa, ensuring that they receive high-quality education that prepares them for their futures.

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