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Fostering innovation and multi-sector collaboration: The Tshwane Varsity Hackathon's impact on empowering historically disadvantaged university students

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Abstract

The challenge of fostering innovation and multi-sector collaboration within historically disadvantaged universities remains pressing, as students often face limited access to industry-standard tools and real-world problem-solving experiences. This study investigates how the Tshwane Varsity Hackathon serves as a dynamic platform to address these challenges, particularly through the lens of the quadruple helix model of innovation. The proposed conceptual framework positions the hackathon as a central innovation hub, with directional arrows radiating outward to the four helices—academia, industry, government, and community—illustrating the active, reciprocal flow of innovative knowledge, practical skills, and co-created solutions from the hackathon into each sector. A qualitative content analysis was conducted, drawing on official documents and academic literature from databases such as EBSCOhost, Scopus, and Google Scholar. Findings reveal that Tshwane Varsity Hackathon 2023 significantly enhanced multi-sector collaboration, exposing historically disadvantaged university students to industry-standard tools and methodologies while developing both technical competencies and soft skills. Participants engaged with real-world challenges, which strengthened their problem-solving abilities and entrepreneurial aspirations. The hackathon also fostered interdisciplinary teamwork, effectively bridging theoretical academic knowledge with practical application. The justification for this new framework arises from limitations in traditional quadruple helix models, which often depict innovation as a

unidirectional flow toward a central hub, overlooking the proactive role of hackathons in distributing innovation outputs back into the system. This study contributes to understanding how hackathons empower historically disadvantaged university students by connecting them with diverse sectors, ultimately enhancing their capacity to innovate and succeed in the competitive job market.

Keywords: *Collaboration; innovation; multi-sector; Tshwane Varsity Hackathon; skills*

Introduction

Hackathons have become increasingly recognised in higher education as dynamic platforms that foster innovation, promote interdisciplinary collaboration, and cultivate practical, work-relevant skills. Defined as time-constrained, intensive events, often with competitive elements, hackathons offer participants the opportunity to collaborate on solving real-world problems (Brereton, 2020; Calco & Veeck, 2015; Oyetade et al., 2023). These events have gained particular prominence in science, technology, engineering, and mathematics (STEM) fields, providing opportunities for students to gain hands-on experience in areas that bridge the gap between academic theory and practical application (Buchem & Leiba, 2022; Gama et al., 2023). By creating an immersive environment, hackathons encourage the development of competencies in critical thinking, problem-solving, and technological innovation (University of the Western Cape, 2023).

Globally, universities and industries have increasingly used hackathons as a mechanism for co-creation, knowledge exchange, and talent development (Gama et al., 2023; Komssi et al., 2014). These events provide a collaborative space for students, professionals, and industry leaders to engage in solution-oriented problem-solving, driving innovation and offering a platform for career and entrepreneurial development. Hackathons also facilitate the exchange of knowledge between academia and industry, equipping students with the practical skills required in the job market (Oyetade et al., 2023). However, in South Africa, the role of hackathons becomes even more critical given the challenges posed by educational inequality and youth unemployment, particularly within historically disadvantaged universities (HDUs).

In the past, historically disadvantaged universities in South Africa have been hindered by systemic challenges, including limited access to resources, infrastructure, and exposure to industry opportunities

(Risinamhodzi & Heymann, 2023). These constraints create significant barriers to student success, particularly for those from marginalised communities. Hackathons, however, present a unique solution by providing students with the opportunity to engage in skill development, mentorship, and networking. These events often become crucial interventions, as they not only improve students' technical skills but also offer the chance to build relationships with industry leaders who can offer guidance and access to professional networks (Oyetade et al., 2023; Risinamhodzi & Heymann, 2023).

Hackathons are particularly valuable in historically disadvantaged universities, where they bridge the divide between theoretical knowledge and real-world experience. These events offer students the opportunity to develop practical skills that are often absent from the formal curriculum (Gama et al., 2023). Moreover, hackathons promote collaborative work, encouraging students from diverse backgrounds to work together on solving complex problems, fostering both personal and professional growth. The emphasis on innovation within hackathons equips students with the ability to think critically and creatively, preparing them to address societal challenges through technology and entrepreneurship. Furthermore, hackathons provide participants with mentorship from industry professionals, opening doors to career development and opportunities that might not otherwise be available to students from underrepresented communities (Oyetade et al., 2023; Gama et al., 2023).

One such initiative is the Tshwane Varsity Hackathon (TVH), hosted annually by the Tshwane University of Technology (TUT) since 2018 (Phurutsi, 2023). TVH was established to promote innovation and entrepreneurship among students, particularly those from historically disadvantaged communities. Over the years, TVH has evolved into a flagship event within the University Hackathon Series (UHS), attracting participants from universities across the City of Tshwane, including the University of Pretoria (UP), Sefako Makgatho Health Sciences University (SMU), and the University of South Africa (UNISA) (Phurutsi, 2023; van Aalst et al., 2025). The hackathons offer immersive, hands-on experiences in areas such as agile software development, cloud computing, and digital solution design. In addition to technical training, TVH incorporates empowerment workshops, mentorship sessions, and practical problem-solving phases, which are designed to equip students with the skills and knowledge necessary to thrive in a rapidly evolving technological landscape (Phurutsi, 2023).

While existing research has explored the pedagogical and technological benefits of hackathons (Happonen et al., 2020; Kamal et al., 2024; Oyewo & Umoh, 2022), there remains a significant gap in understanding the role of cross-sector collaboration in the success and sustainability of hackathons, particularly in the context of historically disadvantaged universities. Hackathons in these resource-constrained environments often rely on partnerships between academia, industry, and civil society to deliver impactful educational outcomes. These collaborations are crucial in overcoming institutional limitations, ensuring that hackathons can offer students a comprehensive learning experience that extends beyond the classroom (Oyetade et al., 2023).

Moreover, there is limited research that investigates the long-term impact of hackathons on students' career development, innovation capacity, and entrepreneurial intent. While hackathons are seen as effective in the short term for developing specific skills, less is known about how the mentorship, knowledge-sharing opportunities, and industry exposure offered during these events influence students' career trajectories and entrepreneurial ambitions (Risinamhodzi & Heymann, 2023). For students in historically disadvantaged universities, the skills and networks gained through hackathons could have a lasting effect on their future career paths, but more evidence is needed to determine the scope and scale of these outcomes.

This study seeks to address these gaps by examining the Fifth Annual TVH in 2023, with three specific objectives:

a) To examine the role of multi-sectoral collaboration in facilitating innovation during the 2023 TVH.
b) To explore the technological enablers and key drivers that support innovation and effective collaboration in hackathon settings.
c) To assess how hackathons can be leveraged to generate socio-economic impact through inclusive participation and cross-sector partnerships.

These objectives will guide the inquiry and ensure that the study provides a comprehensive evaluation of the impact of hackathons in historically disadvantaged universities. By focusing on the TVH, this research will offer insights into the transformative potential of these events in fostering student innovation, career readiness, and entrepreneurial spirit, particularly in contexts marked by limited resources and opportunities.

The following questions were developed in line with the aims of the study to guide this study's focus on collaboration, innovation, and the outcomes of the Fifth Annual TVH in 2023:

a) How did multi-sector collaborations among universities, industry, government, and communities contribute to innovation at the Fifth Annual TVH in 2023?
b) What technological tools and innovation drivers were critical in supporting teamwork, problem-solving, and solution development during the hackathon?
c) In which ways do hackathons like the TVH contribute to socio-economic development and create opportunities for sustainable, scalable solutions?

These questions provide a focused and comprehensive approach to evaluating the hackathon's effectiveness and its potential to empower students in meaningful ways. Therefore, this study aims to contribute evidence-based recommendations for enhancing the role of hackathons in historically disadvantaged universities in South Africa and other similar educational environments, ensuring that such platforms continue to empower students to meet the challenges of the 21st-century workforce.

Conceptual framework

The conceptual framework underpinning this study is based on the quadruple helix model of innovation, which emphasises the dynamic collaboration between four key societal sectors: academia, industry, government, and community. This model posits that innovation is most effective when these sectors co-create solutions by sharing resources, knowledge, and expertise to address complex societal issues (Carayannis & Campbell, 2009; Pohl & Hadorn, 2007). Innovation is rarely the result of a single actor working in isolation. Rather, it emerges from the interdependence of diverse stakeholders, each bringing unique perspectives and strengths. Through collaboration, these actors develop solutions that are not only technically sound but also socially relevant, inclusive, and sustainable (Etzkowitz & Leydesdorff, 2000).

This study adopts the quadruple helix model of innovation as conceptualised in the GRRIP Project (Figure 1). The diagram has been adapted to show arrows pointing inward toward each of the four elements—academia, industry, government, and community—to

symbolically illustrate the convergence of efforts and mutual contribution toward innovation.

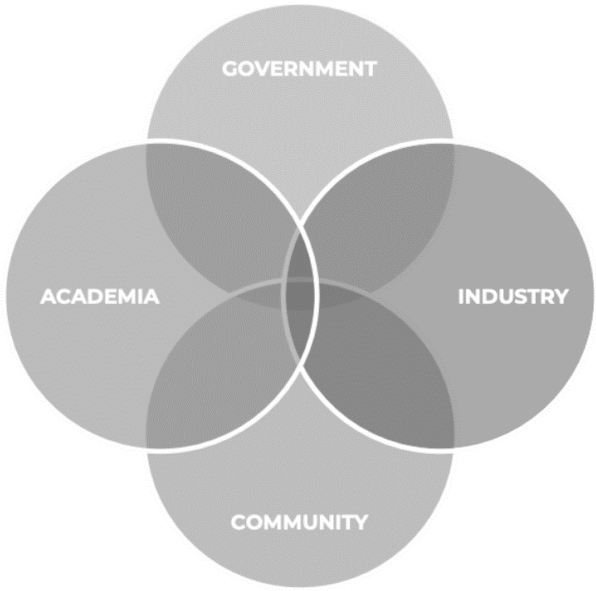

Figure 1: Quadruple helix model of innovation

Quadruple helix model of innovation: Academia, industry, government, and community

a) Academia: Universities and research institutions serve as engines of knowledge creation, intellectual development, and human capital formation. Academic research provides the theoretical and empirical foundation for technological and societal advancement. Through collaboration with industry and government, academic output becomes more responsive to real-world challenges (Carayannis & Campbell, 2009; Yende & Haskins, 2023).
b) Industry: The private sector is crucial in translating knowledge into practical innovations. Industry provides the infrastructure, technical know-how, and funding necessary for scaling solutions. Engagement with academia and government facilitates access to cutting-edge research and a skilled talent pool, thus accelerating innovation (Leydesdorff & Etzkowitz, 2001).
c) Government: Public institutions shape the enabling environment for innovation by enacting supportive policies, regulations, and funding structures. Government initiatives often align with broader national

objectives, such as South Africa's National Development Plan (NDP), and facilitate intersectoral collaboration (Carayannis & Campbell, 2009).

d) Community: Community involvement ensures that innovation is grounded in the lived experiences and priorities of the people it aims to serve. Local participation contributes to the development of inclusive, context-specific, and socially accepted solutions, reinforcing democratic and sustainable innovation practices (Pittz & Adler, 2016).

Hackathons as a platform for multi-sector collaboration

Hackathons provide a practical mechanism for operationalising the quadruple helix framework. Hackathons bring together students, professionals, government officials, and community stakeholders to co-create solutions in real time (Oyetade et al., 2022; Risinamhodzi & Heymann, 2023). These events are particularly impactful for students from historically disadvantaged universities, offering exposure to industry tools, collaborative problem-solving, and the development of socially impactful innovations. For example, the Fifth Annual TVH in 2023 exemplified the quadruple helix in action. Participants applied methodologies such as Agile Scrum and cloud computing to address pressing societal challenges. The event demonstrated how hackathons can simultaneously align educational goals, industry standards, government priorities, and community needs (Phurutsi, 2023).

New framework: Hackathons as innovation catalysts

This study introduces a new conceptual framework that reconceptualises hackathons as pivotal innovation catalysts within the quadruple helix model. Traditionally, innovation models depict a unidirectional flow of inputs converging toward a central hub; however, this framework advances a dynamic perspective where hackathons serve as outward-projecting innovation engines. Positioned at the centre of the model, hackathons act as energising nodes that actively generate, refine, and disseminate ideas, skills, and collaborative solutions to each of the four helices—academia, industry, government, and community (Oyetade et al., 2023).

This new framework highlights the reciprocal nature of innovation, emphasising the continuous exchange and diffusion of knowledge that enhances each sector's capacity to contribute to systemic change. Therefore, by facilitating interdisciplinary collaboration and community

engagement, hackathons not only aggregate diverse perspectives but also catalyse actionable outcomes that influence academic curricula, industry practices, policymaking, and community development (Gama et al., 2023). Consequently, this framework positions hackathons as critical accelerators of inclusive innovation, particularly within historically disadvantaged universities by fostering experiential learning, bridging innovation gaps, and by promoting socially relevant solutions that resonate across the quadruple helix system.

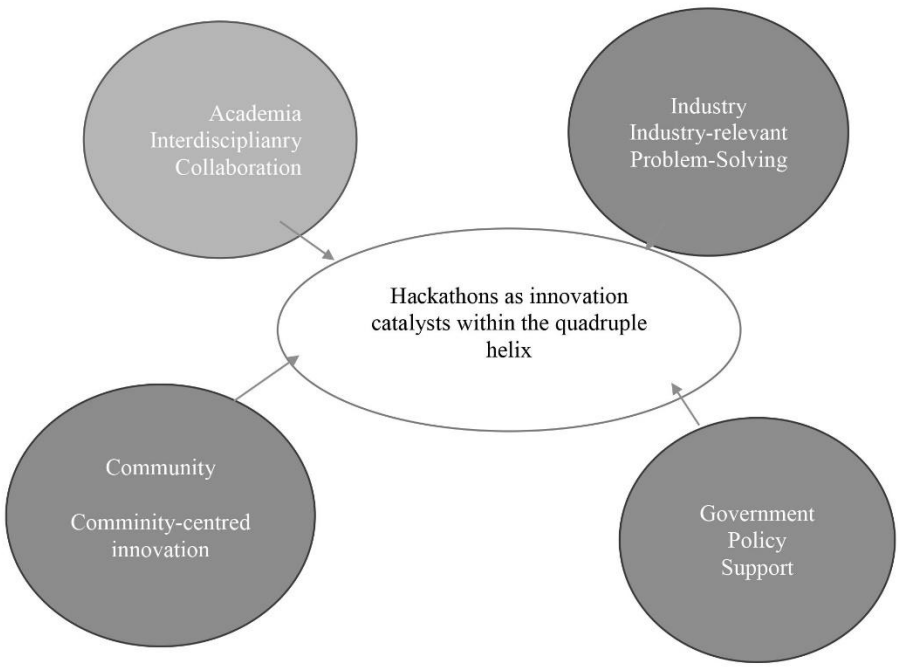

Figure 2: Hackathons as innovation catalysts within the quadruple helix

Within this new framework, hackathons serve as dynamic hubs where interdisciplinary teams rapidly engage in practice-based innovation. Hackathon hubs play a crucial role in empowering students, especially those from historically disadvantaged or underrepresented groups, by offering experiential learning environments that foster creativity and practical problem-solving skills. Through the generation of actionable innovations, hackathons contribute sustainable solutions that feed back into and energise each sector of the quadruple helix—academia, industry,

government, and community—thus promoting systemic change. The framework emphasises a continuous, reciprocal flow of knowledge and resources, illustrating that hackathons do not merely gather ideas but actively distribute innovative outputs outward to influence policy, enhance academic curricula, drive industry practices, and address community needs. Overall, this conceptualisation redefines hackathons as innovation accelerators that amplify collaborative efforts across the quadruple helix, bridging innovation gaps—particularly within historically disadvantaged universities—while fostering inclusive participation, improving career readiness, and generating socially impactful solutions (Oyetade et al., 2023; Gama et al., 2023).

Justification for proposing a new conceptual framework

The justification for proposing a new conceptual framework featuring directional arrows radiating outward from hackathons to the four helices—academia, industry, government, and community—arises from important limitations and gaps in existing innovation models. Traditional quadruple helix representations often depict each helix as an isolated node funnelling ideas inward to a central hub, portraying innovation as a largely passive, unidirectional process. This perspective fails to capture the dynamic, generative role of hackathons as active innovation engines that produce and disseminate practical solutions back into the broader system. By reversing the arrows to flow outward from hackathons, this framework better reflects the reciprocal and continuous exchange of knowledge and skills that energise each sector (Oyetade et al., 2023).

Hackathons are not mere meeting points; they are vibrant, time-bound accelerators of interdisciplinary collaboration and rapid problem-solving. This model explicitly acknowledges their catalytic influence in driving innovation across sectors, fostering a more interactive and cyclical ecosystem (Gama et al., 2023). Moreover, the framework foregrounds the inclusive nature of hackathons, highlighting their capacity to engage marginalised and underrepresented groups, particularly students from historically disadvantaged universities, as active contributors rather than passive beneficiaries. Embracing students as active contributors aligns with growing demands for socially relevant innovation that addresses systemic inequalities and broadens participation.

Additionally, the framework bridges theory and practice by positioning hackathons as intermediaries that translate academic research into tangible, context-specific innovations distributed to all four helices. This bridge

supports sustainable, locally tailored solutions to complex challenges. The outward flow also strengthens policy and educational alignment by enabling hackathon outcomes to inform government strategies, academic curricula, industry practices, and community development initiatives, thereby enhancing the coherence and impact of the overall innovation ecosystem.

In sum, this proposed framework offers a more holistic, realistic, and socially responsive understanding of hackathons within the quadruple helix model, providing researchers, practitioners, and policymakers with a valuable tool to promote inclusive, collaborative innovation for sustainable development.

Methodology

For this article, a qualitative research methodology was used with content analysis as the primary methodology. Murray (2010) defines qualitative research as a method that permits the researcher to "de-mystify perceptions by seeking to understand precise phenomenon or experience". A qualitative research method helps the researcher articulate how people understand concepts (Murray, 2010; Rosaline, 2008). The qualitative research method identifies detailed themes, patterns, and circumstances in an identified body of material, concentrating on methods, understanding, beliefs, and principles. Furthermore, content analysis was adopted in this article because it offers a flexible and interpretive framework suited to understanding the nuanced interactions, experiences, and meanings embedded in the collaborative innovation practices observed during the Fifth Annual TVH in 2023. Content analysis, in particular, enabled an in-depth examination of textual and verbal data to uncover recurring patterns, themes, and contextual insights central to the multi-sector collaboration that characterises hackathons.

Data collection process and duration

Data for this study was collected over a 12-month period, from January 2024 to January 2025, allowing for a comprehensive and longitudinal analysis of the Fifth Annual TVH in 2023. The data sources for the research were varied and included both primary and secondary materials to ensure a well-rounded approach. Primary sources included official documentation and reports from the Fifth Annual TVH in 2023, which provided direct insight into the event's structure, outcomes, and the

collaborative innovation practices observed. Secondary sources were also crucial for providing theoretical and contextual backgrounds. These included a wide range of academic articles, books, book chapters, and policy literature related to hackathons and innovation practices, as well as literature on collaboration in multi-sector environments.

To ensure a comprehensive and rigorous collection of relevant academic literature, the researcher accessed several databases that are subscribed to by the authors' institution, including EBSCOhost and Scopus. These databases were specifically chosen for their extensive, peer-reviewed content, which spans a wide range of disciplines and research on hackathons, innovation, and collaboration. By using these sources, the study was able to compile a diverse set of academic articles that not only focus on hackathons but also explore related themes such as innovation, technology-driven collaboration, and the evolution of multi-sector partnerships.

The combination of primary sources (such as event reports and stakeholder data) and secondary sources (academic articles and literature from high-quality, reputable databases) ensured a rich, well-documented data collection process. This comprehensive approach was essential for understanding the complex dynamics of hackathons and their role in fostering collaborative innovation across various sectors.

Challenges and mitigation strategies

One of the primary challenges encountered during the data collection phase was the limited availability of academic literature on hackathons within the South African context. To address this, the scope of literature was broadened to include international studies and grey literature, such as conference proceedings and organisational case studies. Additionally, informal interviews and observational data from stakeholders were used to supplement the gaps.

Data validation

To ensure the trustworthiness and credibility of the findings, a triangulation approach was adopted. The triangulation involved cross-verifying data from multiple sources to ensure consistency and to strengthen the validity of emerging themes. Peer debriefing and member-checking were also employed where appropriate to confirm interpretations.

Data analysis and presentation

Thematic content analysis was conducted following Braun and Clarke's (2006) six-step process: data familiarisation, coding, theme development, theme review, theme definition, and final reporting. The analysis aimed to identify core themes related to stakeholder roles, innovation processes, and sectoral collaboration. These themes are presented in the findings section through narrative explanations supported by direct quotations, excerpts, and cross-referenced literature, providing a rich and contextually grounded interpretation of the data.

Contextualising the findings of this study

The findings of this study stress the transformative role of collaboration across multiple sectors in driving innovation, as demonstrated by the Fifth Annual TVH in 2023. This research highlights that the involvement of diverse stakeholders—who provided mentorship, resources, and expertise—was a key factor in creating an environment conducive to innovation. Hackathons are framed as more than competitive programming events; they serve as powerful platforms that bridge the gap between sectors, harnessing collective strengths to develop impactful, scalable solutions for regional challenges.

Multi-sector collaboration for innovation

The literature on multi-sector collaboration reveals that partnerships between universities and industries are crucial for stimulating knowledge and technology exchange, benefiting both sectors (Yende & Haskins, 2023). Xue et al. (2020) further emphasise multi-sector collaboration as an essential strategy for fostering innovation. Empirical research on university-industry collaboration underscores its vital role in enhancing graduate employability and driving economic growth, particularly in developing countries (Mbatha, 2021; Yende & Haskins, 2023). These collaborations encourage resource sharing, diversity of perspectives, and synergy, facilitating holistic problem-solving.

Xue et al. (2022) stress that multi-sector collaborations are powerful tools for addressing systemic problems. Leveraging the resources of business, government, and non-profit sectors, these collaborations have a more significant impact than isolated organisations. Academia contributes research and talent, industry provides technical expertise, government

ensures policy alignment, and communities offer contextual insights. Universities have a unique opportunity to engage with businesses, expanding educational opportunities, enhancing resources for higher education, and fostering continuous learning (Mbatha, 2020; Yende & Haskins, 2023). This collaboration ensures that graduates are well-equipped to enter the labour market and contribute meaningfully to global economies. These sectors collectively form an ecosystem that strengthens the effectiveness and impact of hackathons like the Fifth Annual TVH in 2023.

Technological enablers of collaboration and problem-solving

This study highlights the crucial role of technological enablers, particularly Agile Scrum methodologies and cloud computing, in facilitating effective collaboration and innovation during the Fifth Annual TVH in 2023. Agile Scrum, a framework grounded in iterative development, teamwork, and continuous feedback, proved essential for hackathon participants navigating complex, real-time problem-solving environments. According to Ekechi, Okeke, and Adama (2024), Agile Scrum breaks work into manageable sprints, typically lasting two to four weeks, with daily stand-up meetings fostering accountability and rapid adaptation. This iterative process empowered TVH teams to refine their ideas swiftly, address emerging challenges, and align their efforts dynamically with project goals. By emphasising flexibility and cross-functional collaboration, Agile Scrum enhanced communication between diverse team members, which is crucial in hackathons where participants often come from varied academic and professional backgrounds.

Complementing Agile Scrum, cloud computing technologies provided a vital infrastructural backbone for the Fifth Annual TVH in 2023. Bongomin et al. (2020) identify cloud computing as transformative for educational and innovation ecosystems by enabling scalable, accessible, and real-time collaborative platforms. At the TVH, cloud-based tools allowed participants to share code, datasets, and project documentation seamlessly, facilitating uninterrupted teamwork regardless of physical location or device limitations. This accessibility empowered participants to harness computational resources flexibly, accelerating prototype development and testing (Ekechi, Okeke, & Adama, 2024). The scalability of cloud services further enabled teams to experiment with resource-intensive applications without infrastructural constraints. Together, Agile Scrum and cloud computing constituted an integrated technological

foundation that supported agile problem-solving, accelerated learning, and enhanced technical competencies, directly fulfilling the first research objective focused on identifying technological enablers that drive innovation in hackathon contexts.

Key drivers of innovation in hackathons

Hackathons, which gained prominence during the COVID-19 pandemic, have become powerful tools for harnessing creative potential. Oyetade, Harmse, and Zuva (2023) highlight that hackathons stimulate creativity and innovation by bringing together individuals who collaborate intensively to solve specific problems. Buchem and Leiba (2022) further emphasise that hackathons are high-energy events that foster disruptive thinking and creative solutions across various fields, including music, business, education, and more. These events provide a platform for individuals to work together, learn from each other, and develop novel solutions to complex challenges. Effective collaboration, access to advanced technologies, mentorship, and participant creativity are key factors driving innovation in hackathons. The structured use of Agile methods and cloud platforms, alongside a supportive environment, allowed teams to create impactful digital solutions during the Fifth Annual TVH in 2023.

Leveraging hackathons for socio-economic impact

The Fifth Annual TVH in 2023 demonstrated the potent capacity of hackathons to drive socio-economic transformation through inclusive participation and robust multi-sector collaboration. Hackathons like TVH bring together diverse stakeholders—students, academia, industry professionals, government representatives, and community members—to co-create innovative solutions addressing pressing societal challenges. This inclusivity ensures that solutions are not only technologically sound but also socially relevant and culturally sensitive, aligning with community needs and aspirations. Buchem and Leiba (2022) argue that such events foster an ecosystem of creativity and social entrepreneurship, where participants are motivated to develop solutions with real-world impact rather than purely academic or commercial value.

The TVH event exemplified how strategic partnerships across the quadruple helix—academia, industry, government, and community—can pool resources, expertise, and networks to nurture scalable, sustainable

innovation. Despite common challenges such as conflicting priorities between sectors and intellectual property concerns, these partnerships enabled the hackathon to function as an incubator for entrepreneurial ambitions and career development. Participants gained access to mentorship, industry-standard tools, and practical problem-solving experiences, which enhanced their employability and entrepreneurial mindsets. Empirical studies (Byrne et al., 2017; Mbatha, 2020) reinforce that such collaborative platforms significantly contribute to regional socio-economic development by generating solutions tailored to local contexts.

This study's findings underscore the need for future hackathons to prioritise cross-sector collaboration explicitly and embed scalability in project design to maximise socio-economic impact. By doing so, hackathons can become sustainable catalysts for addressing Africa's complex socio-economic challenges, fostering innovation ecosystems that support inclusive growth, job creation, and community empowerment, thereby meeting the third research objective.

Discussions of the findings

This study's findings demonstrate that hackathons serve as pivotal platforms for fostering innovation through multi-sector collaboration among academia, industry, government, and community. Positioned within the quadruple helix model, hackathons catalyse the convergence of diverse knowledge, expertise, and resources to address complex societal challenges.

The findings are consistent with prior research, which recognises hackathons as key mechanisms that promote cross-sector collaboration and innovation (Brereton, 2020; Calco & Veeck, 2015; Oyetade et al., 2023). Innovation is rarely the product of isolated efforts; it flourishes through the active interplay of the quadruple helix sectors, combining academic research, industry insights, government policies, and community needs to produce holistic, sustainable solutions. Hackathons provide a structured and time-bound environment that nurtures this interaction, facilitating the co-creation of solutions that are innovative, practical, and socially responsible (Oyetade et al., 2022; Risinamhodzi & Heymann, 2023).

Findings from this study offer further evidence that indicates that hackathons transcend traditional sectoral boundaries, creating dynamic spaces where knowledge and expertise flow reciprocally among participants. This outcome aligns with the conclusions of Happonen et al.

(2020), Kamal et al. (2024), Oyewo and Umoh (2022), Phurutsi (2023), and van Aalst et al. (2025), all of whom highlight hackathons' role in enhancing cross-sector collaboration and addressing multi-dimensional challenges. In the South African context, such hackathon events help bridge the gap between academia and industry by providing students access to tools and practical experiences often unavailable within conventional curricula.

Hackathons offer vital experiential learning opportunities, particularly for students from historically disadvantaged universities, providing opportunities for student engagement with industry-standard tools and collaborative methodologies and thereby enhancing their employability and entrepreneurial capabilities (Oyetade et al., 2023). This focus on students in collaboration with the helix aligns with the conceptual framework that situates hackathons as dynamic hubs from which innovation outputs radiate outward to energise each helix.

Students gain considerable value from participation, with enhanced problem-solving skills and creativity emerging as key benefits. Engagement with professionals from industry and government enables students to witness the real-world application of their academic knowledge, thereby bridging the often-cited gap between theory and practice. This exposure to current technologies and methodologies fosters career readiness and entrepreneurial thinking, which are essential in today's competitive job market (Oyetade et al., 2023; Risinamhodzi & Heymann, 2023). The findings strongly support the quadruple helix framework, which emphasises the symbiotic collaboration among sectors as vital for driving innovation (Carayannis & Campbell, 2009; Pohl & Hadorn, 2007). The study findings further reveal that hackathons cultivate a rich, multi-sectoral collaborative environment. Diverse participation—including students, industry professionals, government representatives, and community members—ensures that the solutions developed are not only innovative but also contextually relevant and socially impactful (Oyetade, Zuva, & Harmse, 2022; Risinamhodzi & Heymann, 2023). Such inclusivity fosters creativity while grounding innovation in real-life challenges, which is especially important for students in historically disadvantaged universities, where access to industry-standard experiences may be limited (Phurutsi, 2023).

Community engagement emerges as a crucial component of this collaborative model. The findings show that involving community stakeholders ensures innovations respond directly to local priorities and social realities, enhancing their relevance and sustainability. This participation amplifies the social impact of hackathons and aligns with

research advocating community inclusion in innovation processes (Oyetade et al., 2022; Risinamhodzi & Heymann, 2023). By integrating community perspectives, hackathons foster socially responsible innovations that contribute meaningfully to local development and inclusivity.

This emphasis on community aligns closely with the quadruple helix model, which integrates social dimensions into the innovation ecosystem alongside academic, industrial, and governmental sectors. Such integration guarantees that innovation outputs are not solely technically feasible but also ethically sound and oriented toward broader societal goals (Carayannis & Campbell, 2009). Community involvement supports sustainable development by ensuring that solutions address genuine societal needs rather than abstract or disconnected challenges.

Overall, the study confirms the quadruple helix model as a robust conceptual framework for understanding how hackathons function as innovation catalysts. The collaborative environment fostered by hackathons facilitates the active exchange of ideas, skills, and resources, leading to solutions that effectively tackle complex societal problems. The inclusion of students from historically disadvantaged universities within this framework is particularly significant, as it offers these historically marginalised groups pathways to develop skills, expand networks, and improve career prospects (Oyetade et al., 2023; Risinamhodzi & Heymann, 2023).

In conclusion, hackathons provide a distinctive and powerful platform for driving inclusive, multi-sector innovation. By engaging stakeholders across academia, industry, government, and community, they create a fertile environment for knowledge-sharing and joint problem-solving. This study's findings highlight the importance of embedding hackathons within the quadruple helix framework to amplify their transformative potential, especially in contexts marked by inequality and limited access to innovation resources. The insights gained here offer valuable guidance for policymakers, educators, and industry leaders seeking to leverage hackathons as tools for social inclusion, skills development, and sustainable innovation in both local and broader settings.

Recommendations

Based on the findings, it is recommended that to enhance future initiatives like the Fifth Annual TVH in 2023, fostering stronger multi-sector collaboration is essential. Academia should expand its role by integrating

more industry-relevant training, such as Agile methodologies and cloud computing tools, to better prepare students for real-world challenges. Industry partners can increase mentorship opportunities and provide advanced technological resources, ensuring solutions remain practical and scalable. Additionally, aligning hackathon objectives with government policies, such as the government's National Development Plan, can attract funding and ensure broader adoption. Community involvement should be amplified through participatory planning and feedback mechanisms to ensure innovations address local needs effectively. Establishing mechanisms for post-event knowledge sharing, such as publishing success stories or creating online repositories, will inspire replication of the model. Lastly, a robust monitoring and evaluation framework should be implemented to track long-term impacts and continuously refine the collaborative model for greater societal and economic benefit.

Conclusion

This study examined the Fifth Annual TVH in 2023 and its role in promoting innovation, multi-sector collaboration, and long-term student development, with a particular focus on students from historically disadvantaged universities. The study explored the hackathon's structural design, implementation strategies, and educational objectives, assessed the effectiveness of collaboration, and evaluated the long-term impact on students' innovation capacity, career growth, and entrepreneurial aspirations.

This study found that the hackathon did facilitate innovation through multi-sector collaboration (RQ1); that the technological and methodological tools like Agile Scrum practices and cloud-based technologies did drive teamwork, innovation, and solution development (RQ2); and that there were significant socio-economic and entrepreneurial benefits for students from historically disadvantaged universities (RQ3). The findings highlight that hackathons promoted the active engagement of academia, industry, government, and community stakeholders, aligning well with the quadruple helix model. By positioning hackathons as dynamic, outward-facing catalysts, the study demonstrated how reciprocal knowledge and innovation flow between the four helices.

The findings highlight the positive impact of the quadruple helix model, which involves collaboration between academia, industry, government, and community, on driving innovation and enhancing educational experiences for students. This model not only helps students

address real-world challenges but also equips students with a comprehensive understanding of technological and social needs. The hackathon exposed historically disadvantaged university students to industry-standard tools like Agile Scrum and Cloud Computing, fostering innovation and adaptability in the job market.

The educational objectives of the hackathon emphasised bridging the gap between students' academic knowledge and practical application. By incorporating industry practices and community insights, the event promoted skill development, interdisciplinary collaboration, and problem-solving. Bridging this gap enabled students to develop both technical and soft skills, enhancing their preparedness for the workforce. The collaboration between stakeholders was effective, creating an ecosystem where student innovation flourished and led to solutions addressing issues in education, healthcare, and the environment.

The long-term impact of the Fifth Annual TVH in 2023 on students was significant, particularly in enhancing students' innovation capacity, career development, and entrepreneurial aspirations. Students gained exposure to real-world challenges, collaborative opportunities, and industry networks. For historically disadvantaged university students, the hackathon provided a platform to demonstrate their potential and gain visibility among industry professionals. Many students expressed increased confidence and a desire to pursue careers in technology, innovation, and entrepreneurship.

The findings also revealed that the design and implementation of the Fifth Annual TVH in 2023 played a crucial role in creating an environment that nurtured innovation. Success was attributed to the collaboration among the four sectors, each contributing its strengths. Academia provided intellectual expertise and mentorship, industry offered practical tools and real-world problem scenarios, government ensured alignment with national goals, and the community ensured relevance to local issues.

The study concludes that the Fifth Annual TVH in 2023 was embedded within a collaborative helix framework that has the potential to strengthen Africa's innovation ecosystems by bridging academic knowledge, industry expertise, government policy, and community needs. The multi-sectoral collaborative value of hackathons fosters innovation and student development, particularly among historically disadvantaged university students. This study recommends the importance of continued investment in hackathons to provide equal opportunities for underrepresented groups and calls for future research to optimise

stakeholder collaboration and evaluate the long-term outcomes of such events.

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