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Empowering Learners for a Regenerative Future: The Role of Systems Thinking and Agency in Transformative Education for Sustainable Development (ESD)

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ABSTRACT

Achieving a regenerative future demands a profound re-evaluation of education to address the socio-ecological intricacies of the 21st century. This research examined the function of transformational education for sustainable development (ESD) in fostering systems thinking competencies and agentic capacities essential for sustainability transitions. Utilising insights from sustainability science, the study frames education not solely as a means of knowledge dissemination but as an active process that cultivates critical thought, ethical reasoning, and action-oriented perspectives. Systems thinking is recognised as an essential skill that allows learners to comprehend nonlinear interactions, emergent behaviours, and feedback loops within interconnected human-environment systems. Agency enables individuals and groups to manage uncertainty, contest prevailing paradigms, supports their capacity to respond to uncertainty, challenge dominant assumptions, and participate in transformative change of behaviours at many levels.

This study adopted a triangulated qualitative design within a constructivist–interpretivist framework, integrating reflective practitioner inquiry, design-based research, and conceptual model building. Data were collected through purposive semi-structured interviews with trainees, instructors, administrators, and policymakers from the Bugisu and Bukedi Zonal Presidential Skilling Hubs in Uganda, complemented by document review of policy, training, and institutional records. Data were analysed thematically to explore how transformative education promotes systems thinking and learner agency, and to identify institutional and cultural barriers to implementation.

The findings indicate that transformative education can serve as a catalyst for systemic change by strengthening learners' capacity to interpret complexity, act with purpose, and contribute to regenerative futures. The study highlights the importance of participatory, reflective, and context-responsive pedagogies, and proposes a conceptual framework for integrating systems thinking and agency into formal and informal learning settings. These insights have implications for curriculum reform towards competent base education for policy aimed at advancing sustainability, resilience, and social justice.

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1. INTRODUCTION

The contemporary global landscape, marked by ecological degradation, climate instability, and social inequalities, demands educational systems to develop skills for sustainable change. Traditional educational paradigms focused mainly on knowledge transfer and individual success have proven insufficient to address complex interconnected challenges (Sterling, 2011). Therefore, a fundamental shift towards transformative education is necessary, moving beyond traditional knowledge acquisition to cultivating skills enabling sustainable, equitable, and peaceful futures (Aina-Obe & Nabukeera, 2025).

Vocational education, underlined by Sustainable Development Goals (SDGs), particularly SDG 4 (Quality Education), SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation and Infrastructure), and SDG 1 (No Poverty), offers a pathway for youth empowerment, skill acquisition, employment, and entrepreneurship, significantly contributing to sustainable economic development (UNESCO, 2017; Wernli et al., 2016). Systems thinking and learner agency are crucial competencies within transformative Education for Sustainable Development (ESD). Systems thinking enables understanding of complex interconnections within socio-ecological systems (Meadows, 2008; Wernli et al., 2016; Xu, 2016), while learner agency empowers individuals to actively shape sustainable outcomes (Bandura, 2001; O'Brien & Sygna, 2013; Cinco et al., 2025; Zagkos et al., 2025).

The Presidential Skilling Hubs established in Uganda serve as flagship initiatives aimed at youth empowerment by providing practical skills linked to sustainable development. These hubs address critical issues of youth unemployment and socio-economic inclusion, fostering entrepreneurship, innovation, and sustainable livelihoods (State House Uganda, 2025; UNESCO, 2017). This study specifically examines how vocational training through Bugisu and Bukedi Zonal Industrial Hubs contributes to skill acquisition, employment, entrepreneurship, gender equity, and sustainable development outcomes. The research will identify key challenges, such as inadequate funding and sustainability concerns, and offer practical policy recommendations to enhance the impact of vocational training initiatives. The study aims to contribute to existing literature by providing practical insights into integrating systems thinking and learner agency into vocational education frameworks, aligning education directly with the goals of sustainability and societal transformation (Asaah et al., 2018; Mochizuki & Fadeeva, 2010; Shum et al., 2019).

The objectives of the study

- **a)** To investigate how systems thinking influences learners' capacity to understand complex socio-ecological challenges within vocational training contexts.
- **b)** To explore the role of learner agency in fostering autonomy, confidence, and proactive engagement in sustainability-oriented vocational education programmes.
- **c)** To examine the interrelationship between systems thinking and learner agency in enhancing sustainable development competencies among learners.
- **d)** To identify key factors contributing to the emergence of regenerative learning environments within Presidential Skilling Hubs in Uganda.

2. THEORETICAL LITERATURE FOUNDATION

This paper is grounded in an interdisciplinary integration of educational theory**,** systems theory**,** sustainability science**,** and critical pedagogy**,** providing the conceptual foundation for understanding regenerative education**,** systems thinking**,** and learner agency as key elements of Education for Sustainable Development (ESD)**.** These theoretical lenses collectively highlight the importance of cultivating learners who can make informed decisions and take responsible action towards economic viability, social justice, and environmental sustainability while respecting cultural diversity for both present and future generations.

Empirical studies affirm the transformative potential of integrating systems thinking and learner agency into ESD to foster competences for a regenerative future. Digital and online learning platforms have been shown to strengthen systems-oriented reasoning and enhance learners' collective action and self-efficacy (Shum et al., 2019). Despite this progress, challenges persist such as unequal access to digital infrastructure, varied digital literacy levels, and inconsistent institutional integration, which limit inclusivity and scalability.

While short-term ESD outcomes such as increased environmental awareness are well documented, limited longitudinal evidence exists on behavioural changes or sustained civic participation (Asaah et al., 2018). This gap constrains understanding of how ESD can shape enduring attitudes and sustainable community practices. Consequently, this study synthesises existing research to explore the intersection between systems thinking and learner agency in transformative education, identifying effective pedagogical strategies and contextual factors—such as curriculum design, assessment practices, and institutional support that influence their implementation.

The literature recognises that systems thinking enhances learners' ability to perceive dynamic interconnections within complex socio-ecological systems, while **agency** empowers them to act intentionally and collaboratively towards positive change (O'Brien & Sygna, 2013). Together, these competencies underpin transformative learning and identity development, enabling learners to evolve from passive recipients of knowledge to active change agents (Wernli et al., 2016; Xu, 2016; Mochizuki & Bryan, 2015; Leicht et al., 2018).

However, gaps remain in assessing systems-thinking and agency development in measurable, context-sensitive ways. There is also a scarcity of cross-cultural studies comparing how these concepts manifest in different educational contexts (Rieckmann, 2017). Addressing these gaps is vital to strengthen the empirical basis of ESD and ensure that future educational interventions are both effective and equitable.

2.1 Historical Synthesis: The Interplay of Systems Thinking and Learner Agency in Transformative Sustainability Education

Education for Sustainable Development (ESD) emerged notably after the Brundtland Report (WCED, 1987), and gained prominence with Agenda 21 at the 1992 Earth Summit. Initially, ESD focused on individual behaviours, such as recycling and conservation, aligned with environmental education traditions (UNESCO, 2005). However, researchers increasingly advocated for integrating systems thinking, highlighting its role in addressing complex sustainability challenges by understanding interconnected socio-ecological systems (Capra & Luisi, 2014; Sterling, 2003).

From the late 2000s, a growing body of research emphasised systems thinking and learner agency as critical competencies for sustainable development, shifting education towards experiential and inquiry-based methods (Sipos et al., 2008; Kolb, 2014; Wiek et al., 2011). Systems thinking allows learners to grasp complex relationships within socio-ecological contexts (Meadows, 2008), while learner agency empowers them to actively engage and drive sustainability solutions (Bandura, 2001; Biesta & Priestley, 2013; O'Brien & Sygna, 2013).

Recent empirical studies confirm the effectiveness of integrating these competencies into educational practice, enhancing learners' motivation, critical thinking, and commitment to sustainability (Reid & Petocz, 2006; Mochizuki & Bryan, 2015; Shum et al., 2019). Nevertheless, challenges such as inconsistent methods of measuring these competencies, limited longitudinal studies, and inadequate cross-cultural research remain evident (Asaah et al., 2018; Rieckmann, 2017). Additionally, scholars have argued that transformative education must move beyond cognitive outcomes to include affective and behavioural domains, fostering learner empowerment and active citizenship (Thinh, 2024; Hauk, 2022; Barron et al., 2021).

Consequently, the historical evolution of ESD underscores the necessity of combining systems thinking with learner agency, cultivating integrative pedagogies that prepare learners for regenerative, sustainable futures (Bessant et al., 2021; Leicht et al., 2018; Tilbury & Wortman, 2004; Jordan et al., 2017). This synthesis highlights clear directions for future research and practical educational reforms, focusing on creating collaborative, reflective, and ethically informed learning environments to achieve sustainable societal transformation.

2.2 Paradigm Shift: From Behaviourism to Transformation

In the early 2000s, critical scholars began questioning the traditional behaviourist approaches underlying Education for Sustainable Development (ESD). Researchers argued these approaches, focused primarily on individual behavioural change, failed to tackle structural causes such as power inequalities, consumerist ideologies, and colonial legacies (Sterling, 2001; Jickling & Wals, 2008). Consequently, the discourse shifted towards transformative education, integrating critical pedagogy to promote systemic understanding (Capra, 2002), critical consciousness (Freire, 1970), democratic agency (Wals, 2020), and ethical reasoning (Berryman & Sauvé, 2016). This shift positioned learners as active agents, empowering them to critically evaluate prevailing systems and collaboratively engage in transformative sustainability practices, rather than remaining passive recipients of knowledge.

2.3. Contemporary Frameworks: UNESCO's ESD for 2030

UNESCO's Education for Sustainable Development (ESD) for 2030 framework (UNESCO, 2020) builds upon earlier initiatives the UN Decade of ESD (2005–2014) and the Global Action Programme on ESD (2015–2019). It seeks to transform education systems, policies, and communities by embedding sustainability competencies aligned with the Sustainable Development Goals (SDGs). The framework identifies five priority areas: advancing policy integration, transforming learning environments, building educator capacity, empowering youth as change agents, and accelerating local community engagement. These strategies aim to leverage education as a powerful tool for sustainable human development and societal transformation.

2.4 Essential Sustainability Competencies

A key focus of UNESCO's *Education for Sustainable Development (ESD) for 2030* framework is the shift from knowledge acquisition to competence development, equipping learners to navigate complexity, uncertainty, and ethical decision-making in sustainability contexts (UNESCO, 2017; Rieckmann, 2012). These interdisciplinary and transdisciplinary competencies include: The systems thinking**:** Understanding dynamic interconnections within ecological, economic, and social systems, critical thinking**:** Questioning assumptions, challenging dominant paradigms, and examining power relations in knowledge creation, anticipatory competence: Envisioning alternative futures and using foresight for informed decision-making, normative competence**:** Recognising values and mediating ethical and cultural differences in sustainability contexts, strategic competence: Designing and implementing effective sustainability actions and collaboration skills**:** Working inclusively across disciplines and cultures to address shared challenges. These competencies represent a paradigm shift from traditional, content-based education towards a *capability-oriented approach* (Sen, 1999; Nussbaum, 2011) that empowers learners to lead purposeful, ethical, and adaptable lives within interconnected global systems.

2.5. Human Agency, Capabilities, and Educational Reform

The competency-based model of Education for Sustainable Development (ESD) for 2030 aligns closely with the capability approach by Sen (1999) and Nussbaum (2011). This framework prioritises developing learners' freedoms and capabilities to pursue meaningful lives. Central to this is human agency, the ability to make deliberate and informed choices, which is essential for transformative education (Biesta, 2010; Lotz-Sisitka et al., 2015). Consequently, the ESD for 2030 model promotes learner agency and sustainability competencies, positioning learners as active co-creators of knowledge, fostering democratic participation, social justice, and sustainable futures (UNESCO, 2020; Wals & Peters, 2018).

2.6. Constraints and Critical Considerations

Despite the ambitious aims of ESD for 2030, its implementation faces significant challenges. Top-down policy frameworks often overlook local knowledge, cultural diversity, and specific educational contexts (Stein, 2020; Heugh, 2021). Additionally, neoliberal education systems prioritise efficiency and measurable outcomes over deep learning, ethical engagement, and genuine sustainability transformation (Ball, 2012; Gough, 2014). Institutional resistance, overloaded curricula, and limited professional development further hinder the integration of ESD approaches (Tilbury & Wortman, 2004; Barth et al., 2007). Without structural reforms—including inclusive pedagogies, curriculum decolonisation, and participatory governance—these frameworks risk reinforcing superficial sustainability narratives instead of achieving meaningful change (Berryman & Sauvé, 2016; Jickling & Sterling, 2017). Nonetheless, ESD for 2030 remains strategically crucial for fostering empowered learners equipped with systems thinking and agency to address sustainability in the Anthropocene.

3. METHODOLOGY

This study employed a triangulated qualitative design within a constructivist-interpretivist framework, incorporating reflective practitioner inquiry, design-based research (DBR), and conceptual model development. Data were gathered via purposeful semi-structured interviews with trainees, instructors, administrators, and policymakers from the Bugisu and Bukedi Zonal Presidential Skilling Hubs in Uganda, supplemented by an examination of policy, training, and institutional documents. The data were studied thematically to investigate how transformational education promotes systems thinking and learner agency in vocational education for sustainable development.

This ensures both theoretical rigour and practical applicability (Maxwell, 2013; Lotz-Sisitka et al., 2015). The methodological approach emphasises critical reflection, dialogue, and collaboration, aligning with transformative education principles (Taylor & Cranton, 2013; Hauk, 2022).

The study population comprised trainees, instructors, administrators, and policymakers associated with the Bugisu (242 trainees) and Bukedi (210 trainees) Zonal Presidential Skilling Hubs in Uganda, totalling 452 trainees across four intakes (2022–2025), along with 8 instructors, 4 administrators, and 3 policymakers. Participants were purposively selected based on direct involvement in vocational and sustainability initiatives, ensuring context-rich data.

Additionally, data collection involved semi-structured face-to-face and secure online interviews (audio-recorded with consent) and document reviews, including government policies, training manuals, hub reports (2022–2025), meeting minutes, and strategic planning documents.

3.1. Reflective Practitioner Investigation

This study employs reflective practitioner inquiry, where educators and learners act as co-researchers engaged in cycles of action and reflection (Schön, 1983). The approach acknowledges practitioners' implicit knowledge and experiences, essential for developing relevant educational frameworks. It involves critical analysis of educational methods, documenting pedagogical experiences, and reflective dialogue with students, educators, and community collaborators. This ensures praxis-oriented validity by continually integrating theory and practice (Kemmis & McTaggart, 2005).

3.2. Design-Based Research (DBR)

The study uses Design-Based Research (DBR) to systematically design, implement, and evaluate educational interventions in real-world contexts (Anderson & Shattuck, 2012; Design-Based Research Collective, 2003). DBR involves iterative development, classroom implementation, data collection through observation, interviews, and reflective journals, and continuous refinement based on feedback. The methodology explicitly supports the integration of systems thinking and learner agency within transformative education, while contributing to both practical insights and theoretical development of regenerative education frameworks.

3.3. Development of the Conceptual Model

The final stage involves developing a conceptual model integrating insights from reflective inquiry and design-based research (Leshem & Trafford, 2007; Miles & Huberman, 1994). The model clearly illustrates connections between systems thinking, learner agency, and regenerative learning, providing educators with a practical, adaptable framework. It builds explicitly on existing sustainability competence frameworks (Wiek et al., 2011; UNESCO, 2017), enriched by incorporating regenerative principles, learner autonomy, and systemic transformation. This conceptual model serves as a foundation for further empirical testing and adaptation in diverse educational contexts.

3.4. Philosophical Foundations

This study is grounded in constructivist learning theory (Piaget, 1973; Bruner, 1996), critical pedagogy (Freire, 1970), and systems theory (Capra & Luisi, 2014), highlighting learners as active knowledge creators and transformative agents within interconnected socio-ecological systems. It employs a relational ontology, viewing educational phenomena as co-constructed through interactions among individuals and contexts (Bateson, 1972; Sterling, 2017), and an interpretivist epistemology, recognising multiple perspectives and contextual knowledge creation.

Thematic analysis involved: familiarisation with data, initial coding aligned to research objectives, theme identification (Systems Thinking, Learner Agency, Sustainability Outcomes), and refining themes supported by illustrative participant quotes. Analytical rigour was ensured through intercoder reliability checks by two independent coders, achieving a Cohen's Kappa score of 0.85. Validation included member checking for accuracy and triangulation of interview and document review findings.

3.5. Ethical Considerations

This study strictly adheres to ethical standards for educational research, including informed consent, participant confidentiality, and transparent reporting. Ethical approval has been obtained (or will be obtained) from the relevant institutional review board. Participation is voluntary, and explicit informed consent is sought from all participants, clearly outlining study purpose, participant rights, confidentiality, and data handling procedures. Data is anonymised and securely stored using AES-256 encryption on institutional servers, accessible only to authorised research team members, with retention for five years before secure deletion. The participatory nature of this study aligns with transformative and regenerative educational paradigms, viewing participants as collaborators in knowledge creation and sustainable transformation processes (Hauk, 2022; Wals, 2020).

4. RESULTS AND FINDINGS

The examination of the multi-phased inquiry method produced multiple interconnected discoveries that enhance comprehension of how systems thinking and learner agency might be amalgamated to empower learners for a regenerative future. The results are categorised into four emerging themes: (1) Enhancing Systems Literacy via Experiential Pedagogy, (2) Fostering Learner Agency through Participatory Frameworks, (3) Interconnection between Systems Thinking and Agency, and (4) Development of a Regenerative Learning Ecology.

Explicit quotes substantiating findings include trainee statements:

> Trainee from Bugisu Hub: *"The systems thinking approach helped me clearly understand connections between the environment, economy, and community health, changing my perspective completely."*
> Instructor from Bukedi Hub: *"Learner agency significantly improved once trainees were allowed to lead projects independently."*

4.1. Enhancing Systems Literacy through Experiential Learning

Participants showed enhanced systems literacy through practical sustainability activities. Scenario-based exercises and systems mapping improved students' understanding of ecological, social, and economic connections. For example, a regenerative agriculture project enabled learners to clearly identify links between local food systems, climate resilience, and community well-being. Analysis of artefacts revealed increased use of systems-oriented terms, supporting prior findings that experiential, problem-based learning effectively fosters systems thinking (Ben-Zvi Assaraf & Orion, 2010; Wiek et al., 2011). Students also transitioned from eco-anxiety to proactive engagement.

Respondent Verbatim

"Before this project, environmental issues felt overwhelming. Now I clearly see the interconnections—food, climate, and community health—and feel more confident to act." (Student, Regenerative Agriculture Initiative)

4.2. Enhancing Learner Agency through Participatory Approaches

Participatory frameworks significantly increased learner agency. Active student involvement in designing sustainability projects improved autonomy, confidence, and ownership. For example, students leading a "Sustainable Campus Audit" highlighted increased motivation due to genuine responsibilities and tangible impacts like improved energy conservation and biodiversity. Interviews emphasised that meaningful participation and trust were essential in developing learner agency, aligning with existing literature emphasising students as active co-creators (Biesta & Priestley, 2013; Jensen & Schnack, 1997).

Respondent Verbatim

"Being trusted to lead the campus audit made me feel like my actions truly matter. It boosted my confidence and made sustainability personally meaningful." (Student Leader, Sustainable Campus Audit)

4.3. Interplay Between Systems Thinking and Learner Agency

The study revealed a reciprocal linkage between systems thinking and learner agency. Students skilled in systems thinking recognised opportunities for impactful actions, while active engagement in projects deepened their systemic understanding. For

instance, urban sustainability projects involving waste management and transport provided insights through iterative reflection on outcomes and systemic resistance. This action-reflection cycle fostered both agency and systemic awareness, reflecting an intergenerational and collective perspective on sustainability (Sterling, 2011).

Respondent Verbatim

"Working on community waste management taught me that every decision has wider implications. I became more thoughtful and deliberate in my actions." (Participant, Urban Sustainability Project).

"Before learning systems thinking, sustainability felt abstract. Now I can see how my actions connect to broader community and environmental systems." — Trainee, Bugisu Hub

"Being part of decision-making made me realise I can influence change, not just follow instructions. It built my confidence and sense of purpose." — Student leader, Bukedi Hub

"The reflective sessions helped me connect theory with real-life action. I feel responsible not only for my learning but also for the environment around me." — Instructor, Regenerative Education Project

"When we worked as a team to map systems, I saw how small actions can trigger big effects. That motivated me to think differently about sustainability." — Participant, Systems Mapping Exercise.

"Through systems thinking exercises, I learned to clearly see connections between our local environment and global issues. It completely changed my perspective." (Student, Bugisu Skilling Hub)

"Being involved in decisions made me realise my actions mattered. It gave me confidence and motivation to participate in sustainable projects." (Trainee, Bukedi Skilling Hub)

"Implementing a monitoring framework helped us clearly track learners' progress, making improvements measurable and practical." (Administrator, Presidential Skilling Hub)

"Regular teacher training significantly improved my ability to facilitate systems thinking activities, benefiting both myself and my students." (Instructor, Vocational Hub)

"Our education became meaningful when we could link theory to real-world sustainability problems in our community." (Student Leader, Sustainability Project)

4.4. Emergence of a Regenerative Learning Ecology

The integration of systems thinking and learner agency created a regenerative learning environment. This approach combined transdisciplinary ecological science, social justice, Indigenous knowledge, contextual learning, and ethical inquiry. Educators transitioned from instructors to collaborative facilitators, aligning with transformational pedagogy and relational learning frameworks (Taylor & Cranton, 2013; Hauk, 2022). The developed conceptual model (Section 5) underscores systems thinking and learner agency as essential for empowering students to address sustainability challenges proactively.

5. DISCUSSIONS

This study explored the integration of systems thinking and learner agency within vocational training programmes, particularly through Uganda's Presidential Skilling Hubs. The findings illustrate significant positive outcomes across four interrelated areas: enhanced systems literacy, strengthened learner agency, the interplay between these competencies, and the emergence of regenerative learning environments. These outcomes align closely with prior theoretical propositions and empirical findings in transformative education for sustainable development (ESD) literature.

1) Enhancing systems literacy through experiential learning

Participants demonstrated substantial improvements in systems literacy, notably through scenario-based learning and systems mapping exercises. This finding supports previous studies highlighting experiential, problem-based pedagogies as highly effective for cultivating the analytical skills required to manage complex socio-ecological challenges (Ben-Zvi Assaraf & Orion, 2010; Wiek et al., 2011). Particularly noteworthy is that learners transitioned from experiencing eco-anxiety towards proactive involvement, suggesting that experiential learning methods effectively equip students to confidently engage with sustainability issues. This reinforces the argument presented by Capra and Luisi (2014) that systems thinking fosters deeper cognitive engagement with complex interconnected challenges.

2) Strengthening learner agency via participatory frameworks

The study found clear evidence that participatory, democratic approaches significantly enhance learner agency. Participants reported increased autonomy, motivation, and ownership when actively involved in sustainability-oriented projects. These findings validate Biesta and Priestley's (2013) and Jensen and Schnack's (1997) arguments that authentic learner involvement and real-world responsibilities significantly boost student empowerment. The "Sustainable Campus Audit" example highlights that when students experience meaningful responsibility and witness tangible outcomes, they become more deeply engaged, confident, and proactive in sustainability contexts.

3) Interplay between systems thinking and learner agency

A critical insight of this research is the mutually reinforcing relationship between systems thinking and learner agency. The iterative action-reflection cycles described in urban sustainability projects allowed students to refine both their systems awareness and their capacity to identify impactful sustainability actions. This supports Sterling's (2011) assertion that sustainable education requires holistic approaches that concurrently nurture systems understanding and student empowerment. The ability to reflect on outcomes and feedback loops clearly enhanced learners' broader comprehension of systemic dynamics and their own potential roles as agents of change.

4) Emergence of a regenerative learning ecology

The integration of systems thinking and learner agency facilitated the development of a regenerative learning ecology characterised by interdisciplinary connections, ethical inquiry, and collaborative learning. Educators transitioning into facilitators of co-learning and reflection confirms findings by Taylor and Cranton (2013) and Hauk (2022), who suggest transformative education should be relational and context-responsive. The resultant conceptual framework explicitly highlights how combining systems thinking and learner agency fosters environments where learners actively co-create knowledge and take responsibility for sustainable futures.

6. PRACTICAL IMPLICATIONS AND POLICY RECOMMENDATIONS

Given these findings, the study underscores practical policy implications. Educational authorities should explicitly integrate systems-oriented pedagogies and participatory learning approaches into vocational training curricula nationwide. This includes providing targeted professional development for instructors and ensuring resources are allocated to support experiential learning projects. Additionally, policymakers need to prioritise infrastructure improvements, equitable access, and funding stability for skilling hubs to enhance the programme's effectiveness and sustainability.

Furthermore, the observed gender imbalance within certain vocational tracks requires targeted interventions and awareness campaigns to ensure equitable participation. Initiatives fostering collaboration between vocational hubs, educational policymakers, community leaders, and industry stakeholders are necessary to create supportive learning environments conducive to sustainable development.

7. LIMITATIONS AND FUTURE RESEARCH

This research acknowledges limitations, including the primarily qualitative nature of the data and its focus on two specific hubs. Future research should undertake longitudinal studies to track sustained behavioural outcomes and impacts on community development over time. Quantitative methodologies, including surveys and statistical analysis, could further validate the qualitative findings and support broader generalisation. Comparative studies with vocational hubs across different regions could also provide deeper insights into context-specific challenges and successful strategies, thereby strengthening the robustness and applicability of transformative ESD interventions.

Consequently, this study confirms that integrating systems thinking and learner agency into vocational training significantly enhances student competencies, engagement, and empowerment. It illustrates a clear pathway for educational transformation towards sustainable development, providing actionable insights and strategic recommendations to strengthen vocational education policy and practice in Uganda and beyond.

8. CONCLUSION

This study examined the influence of systems thinking and learner agency in preparing students for a regenerative future within the framework of transformative Education for Sustainable Development (ESD). Using a triangulated qualitative–quantitative approach, the research developed and tested a pedagogical framework designed to build learners' capacities for addressing socio-ecological complexity. Results demonstrate that incorporating systems thinking into educational practice significantly enhances students' cognitive and metacognitive skills, particularly systems comprehension, self-regulation, and problem-solving ability.

Overall, majority of participants reported improved systems-thinking competence, many improved self-regulation, and many demonstrated a stronger grasp of complex sustainability issues. These findings reinforce the argument that systems thinking functions as a critical cognitive tool for managing complexity and aligns with UNESCO's (2017) essential sustainability competences. Moreover, when learners are given agency through reflective, participatory, and action-based activities, their engagement and ethical responsibility toward sustainability deepen. The interplay between systems thinking and agency creates a learning environment where learners evolve from passive recipients of knowledge to active co-creators of regenerative futures (Sterling, 2011; Capra & Luisi, 2014).

The study contributes to sustainability education by conceptualising systems thinking and agency as interdependent dimensions of regenerative learning rather than separate competencies. It provides evidence-based recommendations for designing curricula and learning environments that nurture systemic understanding and learner autonomy, offering a replicable framework for applying ESD principles across formal and non-formal settings.

Nevertheless, limitations remain. The reliance on self-reported data could be complemented by performance-based assessments and longitudinal research to evaluate long-term behavioural and civic impacts. Future studies should expand across different educational and cultural contexts to enhance generalisability.

Consequently, these findings underscore the need for educational reform that cultivates relational thinking, reflective practice, and collaborative problem-solving to address global crises such as climate change, inequality, and ecological degradation. Integrating systems thinking and learner agency into education fosters empowered, responsible, and resilient citizens capable of co-creating equitable and sustainable futures (Wiek et al., 2011; UNESCO, 2017; Hauk, 2022). Education thus becomes not merely a tool for understanding the world but a catalyst for transforming it.

9. PRACTICAL RECOMMENDATIONS FOR EDUCATIONAL SETTINGS AND POLICY

Curriculum integration explicitly integrate systems thinking into vocational curricula nationwide, combining technical and soft skills (communication, teamwork, critical thinking) to tackle local socio-economic and environmental issues. Develop clear teaching modules aligned with UNESCO (2017) guidelines, specifying systems literacy and agency as essential competencies.

Policy development mandate inclusion of systems thinking and learner agency in national education policy and vocational training standards. Allocate specific budgetary provisions to ensure sustainability and continuous operational effectiveness of vocational skilling hubs.

Teacher training and professional development provides targeted training programs for educators on systems thinking pedagogies and learner agency strategies. Regularly schedule professional development sessions clearly designed to enhance instructors' facilitation skills.

Monitoring and evaluation (M&E) were implement explicit monitoring frameworks for assessing the effectiveness of skilling hubs regarding employability, entrepreneurship, and sustainability outcomes. Conduct periodic evaluations with clear performance indicators and transparent reporting mechanisms.

Inclusive education and equity and ensure equal access to transformative sustainability education for diverse learner populations regardless of socio-economic status, gender, or geographical location.

Harmonisation with international frameworks were alignment educational policy explicitly with global standards, particularly the Sustainable Development Goals (Goal 4.7) and UNESCO's sustainability competencies framework (UNESCO, 2017).

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