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EARLY CHILDHOOD DIGITAL EDUCATION FOR A SUSTAINABLE FUTURE

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ABSTRACT

This conceptual paper aims to explore the potential of introducing computer science education in early childhood as a means to build a technologically capable generation aligned with Oman's Vision 2040. Oman's national strategy emphasizes economic diversification, innovation, and technological advancement as key sustainable development goals. Achieving these goals requires a workforce equipped with skills in science, technology, engineering, and mathematics (STEM). Learning computer science and technology at an early age can contribute to the development of a technologically literate society and enable children to participate meaningfully in Oman's digital transformation. Early exposure to computer science for preschool and kindergarten students supports the creation of a future workforce that is well-prepared for the demands of a changing economy. This paper is based on a review of existing literature related to early technology exposure and its relevance to workforce readiness and national development priorities.

Keywords: *Early childhood technology education, digital literacy, sustainable development, Oman sustainability goals*

Paper Type: *Conceptual*

INTRODUCTION

Oman's Vision 2040 outlines a strategic shift toward economic diversification by promoting growth in non-oil sectors such as tourism, manufacturing, logistics, agriculture, technology, and innovation (Al-Sarihi, 2020). This forward-looking vision presents a comprehensive roadmap aimed at transforming the nation's economy, society, and governance in response to global challenges and emerging opportunities (Valeri, 2020). Central to this transformation is Oman's transition from a historically oil-dependent economy to a knowledge-based one—a shift essential for achieving sustainable development, fostering technological innovation, and expanding economic opportunities (Al-Sarihi, 2020; Valeri, 2020). By encouraging more diverse economic activities, Vision 2040 seeks to create sustainable employment opportunities for the

growing Omani population. A key component of this strategy is the development of technological capabilities across all levels of education, beginning with early childhood and extending to advanced research and development (R&D) initiatives. This paper explores how Oman can adapt Finland's play-based tech integration model to foster future innovators.

To foster innovation and enhance the efficiency of both public and private sectors, Oman is actively investing in its digital infrastructure. Key initiatives include expanding broadband connectivity, implementing e-governance systems, and developing smart city projects (Al Haziazi et al., 2018). These efforts align with the digital transformation and technological innovation priorities outlined in Vision 2040, which emphasize the need to prepare Omani citizens for future industries (Louis & Saleh 2024). Achieving these goals requires significant investment in human capital, particularly through education in science, technology, engineering, and mathematics (STEM) fields (Sutrisno et al., 2023). Introducing technology at an early age plays a vital role in this process by nurturing creativity and providing children with new tools for self-expression. When technology is used as a medium for creative exploration, it helps children see themselves as active creators and not as mere consumers —developing an early mindset oriented toward innovation and problem-solving (Louis & Saleh 2024).

LITERATURE REVIEW

Oman Strategic Vision 2024

Technology and innovation are critical enablers of a competitive workforce, economic diversification, and environmental sustainability in Oman (Alrawahi, et.al, 2023). Vision 2040 serves as the nation's strategic roadmap toward building a sustainable, diversified, and innovation-driven economy (Tippett et al., 2017). Central to this vision is the commitment to investing in education and digital infrastructure, while fostering a culture of innovation that supports long-term national development in an increasingly dynamic global environment.

Sustainable development is a core pillar of Vision 2040, with an emphasis on integrating environmentally responsible practices across sectors. This includes conserving natural resources, advancing renewable energy, promoting sustainable agriculture, and encouraging the adoption of green technologies (Al-Yahyai, 2023). Education, particularly in science, technology, engineering, and mathematics (STEM), is seen as a vital tool for preparing future leaders equipped with digital literacy and problem-solving skills, capable of driving innovation in fields such as engineering, data science, and information technology (Lillemyr, 2009).

Vision 2040 also supports the integration of technology and innovation within the education system starting from early childhood. This aligns with global research indicating that early exposure to technology fosters cognitive development and better prepares children for advanced learning and innovation (Louis, et.al). Beyond formal education, the vision promotes lifelong learning through technical training, digital literacy programs, and professional development initiatives to ensure that Omani citizens remain adaptable and competitive in the global workforce (Alrawahi et al., 2023).

Another key objective of Vision 2040 is positioning Oman as an attractive destination for foreign direct investment (FDI) in strategic sectors such as technology, logistics, and tourism (Manas, 2020). To achieve this, the country aims to enhance the business environment by strengthening intellectual property laws and cultivating a climate of innovation. Collaborating with leading global technology firms, research institutions, and international partners will facilitate knowledge transfer, support local capacity building, and accelerate technological advancement in Oman.

Importance of Early Childhood Education

Early childhood, spanning from birth to approximately eight years of age, represents a critical period of rapid growth and development that lays the foundation for lifelong well-being, education, and success (Chesloff, 2013). During this time, the brain undergoes its most intense development, forming neural connections at an extraordinary rate. By the age of three, a child's brain reaches approximately 80–90% of its adult size. This period is essential for developing core cognitive skills such as language acquisition, memory, attention, and problem-solving. Research indicates that early cognitive stimulation—through exposure to language, books, and play—significantly enhances literacy and numeracy skills, which are crucial for later academic achievement (Gimbert & Cristol, 2004). Moreover, high-quality early childhood experiences are associated with improved academic performance, higher graduation rates, and increased employment opportunities in adulthood.

Recent research highlights the benefits of introducing technology to young children in structured, age-appropriate ways. When implemented thoughtfully, early exposure to digital tools can enhance children's creativity, problem-solving skills, and adaptability—critical abilities for success in the 21st century (Wan, Jiang & Zhan, 2021). Technology integration during early childhood supports cognitive development by equipping children with the foundational skills needed to thrive in a rapidly evolving digital world.

Play remains a cornerstone of early childhood education, contributing significantly to children's cognitive, social, and emotional development. Through play, children cultivate creativity, collaboration, and a sense of agency—skills that are essential for meaningful learning and well-being (Fielding & Murcia, 2022; Bers, 2018). Scholars and educators increasingly advocate for recognizing play not as a recreational activity but as a vital educational process. Research supports integrating play into the curriculum in purposeful ways that honor and enhance children's natural instincts to explore and create (Bers, 2021).

Combining play with digital learning tools has proven especially effective. Bers (2018), in *Coding as a Playground*, emphasizes that children develop computational thinking skills through play-based coding activities, which teach them to break down complex problems into manageable steps, a foundational skill for real-world problem-solving (Vieira, Chiu & Velasquez, 2023). Technologies such as programmable robots (e.g., Bee-Bots) and coding applications (e.g., ScratchJr) help young learners grasp concepts like sequencing, cause-and-effect, and pattern recognition. These hands-on, trial-and-error experiences promote experimentation, creativity, and cognitive flexibility (Orcos, Arís & Magreñán, 2019).

Adaptability, a key 21st-century competency, is also nurtured through early interactions with technology. When children engage with digital tools and programmable devices, they learn to navigate unfamiliar systems, solve problems independently, and respond effectively to change (Sutrisno et al., 2023). These early experiences help cultivate a mindset of lifelong learning, essential for staying relevant in a fast-changing technological landscape (Krauss, 2021). As technology continues to evolve, individuals must be capable of quickly acquiring new skills. Introducing digital tools in early childhood helps children become comfortable with this constant evolution, better preparing them for future innovations and workforce demands (Kumpulainen, 2018).

Global Experiences: Integrating Technology into Early Childhood Education

As the world becomes increasingly digital and interconnected, introducing technology in preschool and kindergarten has become essential. Developing digital literacy from an early age is critical to preparing children for future educational and professional environments. Early exposure helps children acquire foundational skills such as navigating digital devices, understanding basic technical terminology, and responsibly accessing and evaluating online information (Sutrisno, et.al). These competencies not only support academic success but also foster confidence, curiosity, and adaptability in a technology-rich world (Jahnukainen et al., 2023). As technology continues to shape communication and learning, early digital literacy becomes a cornerstone for future readiness (Goodill, 2017).

Globally, several countries have integrated technology into early childhood education, but a few—such as Finland, South Korea, and Singapore—stand out for their innovative and balanced approaches (Rusitoru, 2020; Sahlberg, 2021). These nations leverage technology to promote creativity, collaboration, and real-world problem-solving while maintaining a strong emphasis on hands-on learning experiences crucial for young children's development (Rezaei et al., 2022). A key to their success lies in aligning technology use with broader curricular goals, ensuring it serves as a tool for enhancing learning rather than an isolated or distracting component (Voogt et al., 2013).

Finland, frequently recognized for its high performance in international education assessments such as PISA, has emerged as a global leader in integrating technology into early childhood education (Rusitoru, 2020). Its approach is grounded in the principles of equality, innovation, and child-centered pedagogy. Finnish early education emphasizes experiential, play-based learning, where technology is selectively and purposefully used to support creativity, social interaction, and critical thinking (Rezaei et al., 2022).

Digital tools in Finland's early learning environments include storytelling applications, interactive nature exploration, digital art, and simple coding games that introduce children to logical sequencing and problem-solving in an engaging, age-appropriate manner (Voogt et al., 2018). This balanced strategy ensures that digital learning complements—rather than replaces—traditional developmental activities.

Educators play a central role in Finland’s technology integration strategy. Rather than using digital tools passively, teachers incorporate them as part of broader, meaningful learning

experiences. They are trained to critically select age-appropriate technologies, balance screen time with physical and social activities, and foster digital skills mindfully (Rusitoru, 2020). Professional development programs equip educators with the knowledge and skills needed to use technology responsibly and effectively in early learning settings.

Parental engagement is another cornerstone of Finland's approach. Teachers work with families to promote responsible technology use at home and extend learning beyond the classroom (Jahnukainen et al., 2023). The national curriculum incorporates digital well-being, encouraging children to develop healthy technology habits from a young age (Rusitoru, 2020). Evidence-based practices guide policy and classroom implementation to ensure that technology supports developmental goals rather than undermining them.

When thoughtfully integrated, technology in early childhood education significantly enhances children's problem-solving skills, creativity, adaptability, and cognitive flexibility. It also nurtures critical thinking and digital literacy—skills essential for thriving in a rapidly evolving world (Kennedy & Sundberg, 2020]. These educational benefits align closely with the goals of Oman's Vision 2040, which prioritizes technology, innovation, and sustainable human capital development. By drawing on successful international models like Finland's, Oman can build a future-ready generation capable of contributing to a diversified and innovation-driven economy.

Preparing for a Globalized, Digital Society

Technology has become an inseparable part of everyday life, and preparing children for a tech-driven world must begin early. Developing digital literacy in preschool and kindergarten equips young learners with the foundational skills necessary to navigate and adapt to an ever-evolving digital landscape. Early exposure to digital tools such as tablets, computers, and educational applications helps children become confident and competent users, facilitating their future interaction with more advanced technologies.

Moreover, integrating technology into early childhood education plays a key role in addressing the digital divide. By ensuring equitable access to digital resources across all socioeconomic backgrounds, it promotes inclusivity and equal opportunity from the earliest stages of learning. This inclusive approach lays the groundwork for broader digital participation and long-term social equity.

In an increasingly interconnected and innovation-driven world, early technology education prepares children for essential 21st-century skills, including digital literacy, critical thinking, coding, and adaptability (Weber & Greiff, 2023). These competencies are vital across a wide range of future careers, particularly within science, technology, engineering, and mathematics (STEM) fields (Alrawahi et al., 2023). Familiarity with digital tools from an early age not only enhances problem-solving and collaboration but also nurtures a global mindset, enabling children to engage confidently in a digital society that transcends borders (Clements & Nastasi, 2013; Valeri, 2020).

This global readiness aligns directly with national development strategies such as Oman's Vision 2040, which prioritizes building a competitive, diversified economy driven by innovation and knowledge. Empowering young Omanis with digital competencies from early childhood supports this vision by cultivating a future workforce equipped to thrive in a global digital economy.

To successfully integrate technology into early childhood education, Oman can draw inspiration from international best practices—particularly Finland's model, which combines technology use with child-centered, play-based learning. However, adaptation to local values, cultural norms, and societal needs is essential. A contextualized, Oman-specific curriculum must be developed with careful attention to policy, curriculum design, teacher preparation, and infrastructure.

A pilot phase involving a selected number of preschools and kindergartens can serve as testbeds for implementation. These prototypes would allow for empirical evaluation and iterative improvement of the curriculum before national scaling. Such a measured approach ensures that the integration of technology supports—not disrupts—developmentally appropriate learning experiences. In this pilot phase, efforts should be made to promote and emphasize the inclusion of the Arabic language as a parallel medium of instruction for digital learning to conserve cultural and linguistic values for future generations in Oman.

Introducing technology in early education should go beyond functional literacy; it should cultivate creativity and innovation. When used thoughtfully, digital tools can become mediums for storytelling, artistic expression, and problem-solving. This creative digital play empowers children to view technology not just as a tool for consumption, but as a platform for invention and imagination (Van Keulen, 2018). By fostering a sense of agency, children begin to see themselves as creators, laying the foundation for lifelong innovation and inquiry.

Sustainable technological advancement depends not only on adopting tools but also on developing the capacity to create and innovate. Introducing technology early in the educational journey ensures that future generations possess the skills and mindset necessary to contribute meaningfully to Oman's digital transformation. As the country moves toward its Vision 2040 objectives, investing in early technology education is both a strategic and sustainable choice—one that builds resilient human capital for a future defined by knowledge, creativity, and innovation.

IMPLICATIONS

This study contributes to the growing body of literature on early childhood education and technological innovation by offering new insights into how the integration of technology at a young age can enhance cognitive development and foster the formation of a tech-savvy workforce capable of thriving in the digital age.

First, from an educational perspective, the study emphasizes that early childhood is a critical period of rapid brain development, during which neural connections are formed at an accelerated rate. This stage of life lays the foundation for lifelong learning, cognitive growth,

and overall well-being. By incorporating technology into early learning environments, children are better positioned to develop essential skills such as problem-solving, logical thinking, and creativity—skills that support not only academic achievement but also the competencies required for sustainable and innovative business and technological practices in adulthood.

Second, the study underscores the increasing relevance of digital literacy and technological knowledge in a world that is becoming progressively more digital and interconnected. Technology and innovation are no longer optional but central pillars for building sustainable human capital. Introducing foundational concepts in computer science and technology during early childhood can help cultivate a society that is technologically fluent and future-ready. This, in turn, supports the development of sustainable business ecosystems, as a technologically literate population is more likely to drive innovation, efficiency, and environmentally conscious decision-making.

CONCLUSION

In conclusion, the integration of technology into preschool and kindergarten education is not only about familiarizing children with digital devices—it is about laying a foundation for lifelong learning, adaptability, and innovation. Early exposure to technology enhances children's cognitive, social, and emotional development, equipping them with essential 21st-century skills such as critical thinking, problem-solving, digital literacy, and creativity. These foundational competencies are crucial for navigating an increasingly complex and interconnected world.

Within the context of Oman's Vision 2040, this early integration becomes even more significant. The Vision outlines a future-oriented national agenda centered on sustainable development, economic diversification, and technological advancement, all of which depend on a well-prepared, digitally literate population. By embedding technology education into the earliest stages of learning, Oman can cultivate a generation of innovative thinkers and responsible digital citizens capable of driving national progress in science, technology, engineering, and innovation.

Moreover, early technology education plays a strategic role in promoting social inclusion and equity. Vision 2040 emphasizes inclusive human development and reducing disparities across gender, geography, and socioeconomic status. Technology, when thoughtfully and equitably integrated, can help bridge the digital divide, ensuring that all children—regardless of background—have access to tools that unlock their full potential. This aligns with broader sustainability goals by fostering a more just, educated, and empowered society.

As this paper has argued, Oman stands at a critical juncture where strategic investments in early childhood education and digital infrastructure can create lasting impact. Drawing on international best practices, particularly those that balance technology with developmentally appropriate learning, Oman can design an educational ecosystem where technology enhances, rather than replaces, meaningful learning experiences.

Ultimately, introducing technology in early childhood education is a forward-looking, nation-building strategy. It empowers children not just as users of technology but as future creators and problem-solvers capable of contributing to Oman's knowledge-based economy and sustainable future. This paper offers a conceptual foundation for further empirical research and policy development aimed at realizing this transformative vision.

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