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Digital Pedagogical Models for Teaching Environmental Education at the Middle Stage of School Education

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Abstract:

Introduction of digital pedagogical models into the Environmental Education (EE) in the middle level of schooling presents radical opportunities in the improvement of ecological literacy, system thinking, and ethical environmental behaviour. Whereas traditional EE practices tend to be based on didactic transmission, on the digital platforms, participatory, inquiry-based, and experiential learning experiences can be achieved and appeal to the cognitive and socio-emotional development of adolescents. This paper reviews some important models of digital pedagogy, such as blended learning, gamified learning, virtual and augmented reality, mobile based citizen science, AI-assisted personalised learning, as potential models to make the middle-stage learners more environmentally conscious. Based on the research conducted in the world and the emergent practices in classrooms, the research claim is that the digital EE should be based on the relational, humanistic, and values-driven pedagogy that fosters empathy, responsibility, and agency towards sustainable futures. The paper concludes with a conceptual model and policy, teacher capacity building and school level implementation recommendations.

Keywords: *Digital Pedagogy, Environmental Education, Middle Stage, Gamification, Virtual Reality, Eco-Pedagogy And Sustainability Education.*

Introduction:

Environmental Education (EE) has become a pressing issue on the world agenda due to environmental degradation, the unpredictability of climate, and the disappearance of biodiversity. The middle stage of schooling (11-14 years old) is the period of development when **Abstract** thinking, ethical thought, and social-ecological understanding start to become more mature (UNESCO, 2021). The Introduction of the digital learning models into EE at this level does not only correspond to modern learning practices but also provides immersive and interactive methods of developing ecological awareness.

Digital pedagogical approaches, including gamification, blended learning, virtual simulations, mobile learning, and AI-driven personalised instruction, have been on the rise as a go-to as transformative technologies in the education field. These models provide immersive, interactive, and student-centred learning routes, which especially work with adolescents who have already been fully integrated into digital cultures (Beetham and Sharpe, 2019).

Digital EE facilitates active investigation, group learning, and context-based discovery and gives students the ability to visualise complex systems, like climate patterns, food webs, and human effects, which are not possible with traditional textbooks (Kuo et al., 2019). As the world is evolving faster with digital transformation, the education systems are compelled to employ the technologically enriched and humanistically based pedagogical approaches.

Literature Review:

Environmental Education seeks to build knowledge, attitudes, skills, and behaviours that are necessary in environmental stewardship. Studies highlight that the pro-environmental dispositions and sustainable habits are formed during the early adolescence period (Chawla and Cushing, 2007). Experiential and inquiry-based models have been widely mentioned as effective to this age group.

Digital pedagogy does not involve the simple application of technology; digital pedagogy involves a deliberate approach to designing learning experiences through the use of technology in order to add value to cognition, collaboration, and social interaction (Beetham and Sharpe, 2019). Digital tools were found to increase motivation, conceptual and socio-emotional participation in EE. Key research findings include:

- Gamification enhances motivation and change in behaviour by combining challenges, incentives, and narrative designs (Sailer and Homner, 2020).
- Virtual reality (VR) enhances the theoretical knowledge about Abstract processes in the environment
- Citizen science platforms develop a scientific identity and agency to look after the environment (Bonney et al., 2016)
- Blended and hybrid models encourage the flexibility and enhanced inquiry because of digital-physical integration (Garrison and Vaughan, 2008).

Nevertheless, researchers warn that technology should be employed in terms of ethical and inclusive use as well as to advance human values instead of technological determinism (Selwyn, 2020).

Among them are the digital divides, readiness of teachers, data privacy, excessive dependence on technology, and insensitivity to context (Selwyn, 2020). Scholars highlight that digital EE should be humanistic, i.e. care-centred, empathetic and ecologically ethical as opposed to technological spectacle.

The long-standing challenges comprise teacher readiness, disparities in digital infrastructure, inequality of access, fragility of curriculum, and apathy towards situating the curriculum to the realities of the local environment (UNESCO, 2021). In the absence of humanistic orientation, digital EE will go instrumental, instead of transformative.

Theoretical Framework:

This study is based on:

i) Constructivism: Students develop the knowledge by engaging in the world of the digital simulation, games, and questioning learning environments (Vygotsky, 1978).

ii) Connectivism: The knowledge is developed through networks: human, digital, and ecological networks; they are congruent with digital learning environments (Siemens, 2005).

iii) Eco-pedagogy: This is based on critical pedagogy of Paulo Freire, which emphasizes environmental consciousness, ethical, and relational (and justice-related) (Kahn, 2010).

The digital pedagogical models are therefore conceptualised as means of generating the relational ecological thinking and not the technological add-ons.

Digital Pedagogical Models for EE at the Middle Stage:

1. **Blended Learning Models:**

Blended learning combines both the traditional instruction with electronic modules to facilitate differentiated learning, student autonomy and inquiry learning. Ecological simulators, online discussions, and online field journals are some tools that augment engagement, reflective learning (Garrison and Vaughan, 2008).

2. **Gamification and Game-Based Learning**

Gamified systems deploy problems and storytelling to foster systems thinking and problem-solving as well as intrinsic motivation. Simulation games such as Eco and SimCityEDU allow learners to interact with ecosystems and observe the impact of human intervention after improving pro-environmental behaviour (Sailer &Homner, 2020).

3. **Virtual Reality (VR) and Augmented Reality (AR):**

Immersive technology like VR and AR will enrich empathy, pro-environmental behaviour, and may create awareness about the cultural and environmental problems (Husamah et al.,2025). The more powerful ecological understanding is supported by immersive modules (e.g. virtual coral reefs or climate simulations).

4. **Mobile-Based Citizen Science:**

Citizen science apps such as iNaturalist and eBird allow students to be resourced in real-time to biodiversity documentation, meaning that they build scientific datasets and are stewards of the ecology. These systems promote observation and data gathering and cooperation with scientific groups (Bonney et al., 2016).

5. **AI-Supported Personalised Learning:**

AI technologies offer flexible learning extensions, automatic feedback, and personalized learning material, which facilitate inquiry-based and self-directed learning. Responsible use of AI can enhance engagement and personalisation of environmental education by different learners (Luckin, 2018).

Conceptual Model: Humanistic Digital Environmental Learning (HDEL)

The HDEL Model is a combination of digital pedagogies and humanistic values of the environment. This has five interrelated elements:

1. **Empathy-Centred Digital Experiences:** VR experiences, digital stories and reflective multimedia projects: VR experiences, digital stories, and reflective multimedia activities are activities that create a connection with non-human life.

2. **Scientific Inquiry and Exploration:** Curiosity and scientific reasoning are provoked by Digital Labs, simulated and interactive games.

3. **Action and Participation:** Mobile based citizen science and digital eco-campaigns encourage the community-based environmental action.

4. **Reflection and Dialogue:** Online Discussions, podcasts and online conversations through digital journals encourage critical thinking about the environment.

5. **Collaboration and Community Building:** Virtual classes, group work, interdisciplinary online portfolios, and peer networks enhance group problem solving of the environment.

The model makes technology a tool of developing responsible, caring, and thoughtful ecological citizens.

Discussion:

Digital technologies have the potential to enhance outdoor learning experiences by bridging the gap between digital and natural environments. Utilizing technologies like AR and web applications boosts student involvement in environmental education (Husamah et al.,2025).

Digital educational paradigms profoundly satisfy mental and emotional demands of middle-staged students. Adolescents react well to participatory, interactive, and immersive learning environments. Digital EE models offer a valuable background whereby students would be able to discover, ponder, and respond to environmental problems.

However, the successful implementation of digital pedagogical models in EE is based on- teacher digital competence, ethical technology use, inclusive infrastructure, curriculum integration, and culturally relevant content.

Digital EE has to be humanistic at its basis, where technology fosters empathy, ethical thoughtfulness, and awareness of interdependence between human and nature. When used strategically, digital pedagogies can assist young learners in becoming more ecologically responsible and contribute to the sustainable futures.

Implications for Policy and Practice:

a) Teacher Professional Development: Teachers need to be given capacity building in various fields such as - digital tool integration, inquiry-based pedagogy, ethical and safe digital practices and contextualising EE to local ecosystems

b) School Infrastructure: Schools should be equipped with- reliable internet, VR/AR labs and mobile devices for field-based learning

c) Curriculum Integration: EE needs to be interwoven in the sphere of science, social studies, arts, and language subjects with the help of digital projects.

d) Assessment Reform: Rote test can be replaced by digital portfolios, project-based assessment and student generated work.

Conclusion:

The opportunities provided through the digital pedagogical models are unprecedented in transforming Environmental Education at the middle stage of schooling. Digital tools could help cultivate curiosity, empathy, moral reasoning and ecological accountability when they are based on humanistic, ecological values. Since young learners have an unpredictable ecological future, it is not only an educational innovation but an ethical necessity to introduce ethical digital pedagogy.

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