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TLIC PAPER

Evaluating a Greek Educational Game for Teaching Mathematics and Natural Sciences

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ABSTRACT

This study introduces KIDEDU (Play – Create – Learn), a digital game-based learning platform developed by an interdisciplinary research team at the University of Piraeus. The project is designed to enhance cognitive engagement and conceptual understanding in mathematics and environmental sciences among Greek primary school pupils aged 6 to 12 years. Structured across three differentiated levels (Grades A–B, C–D, E–F), the game integrates principles of guided discovery learning, differentiated instruction, and curriculum-aligned content to support both individual and collaborative problem-solving. Developed through the collaboration of experts in mathematics, natural sciences, computer science, and medicine, the application bridges formal education materials with immersive digital environments. It aims to provide an alternative pedagogical approach that responds to the evolving needs of contemporary learners and classroom diversity. The broader objective of the project is to promote the scalability of such tools across all levels of education and establish game-based learning as a core instructional method within the Greek educational system. A demonstration of the application's structure and interactive components is provided, highlighting its potential to improve learning outcomes, student motivation, and engagement through technology-enhanced, inquiry-driven learning experiences.

KEYWORDS

digital game-based learning, distance learning, differentiated learning, guided discovery learning

1 INTRODUCTION

The ongoing transformation of digital education in the 21st century continues to shape the ways in which learners interact with knowledge. Among the most impactful innovations are serious games—purposefully designed digital environments that blend entertainment with educational goals. These games have emerged as powerful tools in developing pupils' cognitive, emotional, and social skills by immersing them

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in rich, narrative-driven tasks that require critical thinking and decision-making [18]. In this context, the present paper introduces KIDEDU, an educational 3D video game created for Greek primary school learners between the ages of 6 and 12. The game is designed not only to strengthen subject-specific skills in mathematics and natural sciences but also to encourage broader cognitive development through play-based learning. By integrating pedagogical concepts such as differentiated instruction and guided discovery, KIDEDU aims to provide an alternative instructional framework that reimagines foundational education as both engaging and contextually meaningful.

Contemporary educational discourse increasingly emphasizes the need for learners who are adaptable, self-motivated, and socially conscious, traits aligned with the ideal of lifelong learning. Modern societies now place a high value on individuals who are not only knowledgeable in disciplinary content but who can also collaborate effectively, communicate clearly, and think creatively in solving real-world problems [22]. This reality underscores the urgent need to rethink how learning environments are structured and how pedagogy is enacted. According to Paniagua and Istance [14], prioritizing pedagogy reshapes the teacher's role, moving away from simply transmitting predefined curriculum goals and toward becoming a designer of rich, meaningful learning contexts. In this view, innovation in teaching becomes not just a matter of using new tools but of redefining how learning unfolds. Innovation implies that educators actively adapt their instructional strategies, content delivery methods, and student interactions to respond to technological advances and societal shifts.

Within both formal and informal education, institutions have begun to explore alternative approaches to teaching that leverage digital resources and interactive media. These approaches seek to increase students' cognitive engagement and provide meaningful, real-world connections to learning material [10]. Kalyani and Rajasekaran [8] argue that innovative teaching is not only necessary for the evolving demands of the present but also essential for building resilient educational structures for the future. In this light, games such as KIDEDU are not peripheral distractions but intentional pedagogical tools designed to engage learners in personalized, reflective, and collaborative experiences.

One of the most critical pedagogical shifts in this environment has been the growing recognition of differentiated instruction as a necessary strategy to address classroom diversity. In Greece, educational institutions—particularly in urban centers such as the Attica region—have experienced substantial demographic shifts in recent decades. These include increased immigration, greater socio-economic disparity, and a wider range of learner profiles and cognitive needs [15]. The resulting heterogeneity in classrooms necessitates teaching approaches that go beyond a "one-size-fits-all" model. Differentiated instruction entails the strategic planning of curricula, learning activities, and assessments in ways that respond to individual learners' readiness levels, learning styles, and interests [18].

Research has shown that classrooms embracing differentiated instruction yield better engagement and learning outcomes for a broader spectrum of pupils [3], [19]. Educators who differentiate are more capable of supporting pupils with learning differences, language barriers, or socio-emotional challenges. Despite the international success of this model, its implementation in the Greek educational system has been slow and fragmented. As Mavroudi [11] observes, Greek public schools have only partially adopted differentiated strategies, largely due to a lack of comprehensive teacher training and structural support. Misconceptions persist among teachers, who often perceive differentiation as time-intensive or logistically unfeasible in overcrowded classrooms [16]. Additionally, Mulroy and Eddinger [12]

stress that successful differentiation requires a shift in school culture—moving from rigid, standardized practices to dynamic, learner-centered models.

Further compounding the challenge is the limited integration of digital technologies in many Greek classrooms. Yet, educational technologies—when used thoughtfully—can facilitate differentiated instruction through adaptable content delivery and real-time feedback. Tools such as interactive games, digital platforms, and personalized learning software allow teachers to reach a wider range of learners more efficiently. As Anderson and Krathwohl [1] explain, digital resources can enable the higher-order thinking and self-paced exploration essential to inclusive teaching environments. This is particularly true in early education, where students benefit from multimodal input and varied scaffolding.

The importance of technology in the classroom is further reinforced by Hsu [6], who found that early exposure to IT tools supports scientific inquiry, metacognitive development, and digital fluency. Technological literacy is not simply a "bonus skill" in the modern world. It is a foundational competence that should begin in the earliest years of schooling. By equipping learners with digital skills from a young age, educators prepare them to thrive in a constantly evolving information landscape.

In this framework, KIDEDU emerges not only as a game but as a methodological intervention, one that seeks to reconcile the Greek classroom's traditional structures with the demands of 21st-century pedagogy. By aligning serious game mechanics with differentiated instruction principles and discovery-based learning, it provides a prototype for future educational tools tailored to both local and global contexts.

A critical pedagogical concept gaining renewed attention in contemporary education is that of guided discovery learning, an approach rooted in constructivist theory and driven by the belief that learners construct meaning through exploration and active engagement. In recent years, both primary and secondary educational institutions have intensified efforts to implement teaching methodologies that promote critical thinking, creativity, and transferable skills. These efforts frequently rely on technology-enhanced innovations that facilitate student-centered learning while also supporting the development of higher-order cognitive functions [7], [18]. Within this landscape, discovery-based frameworks—particularly those that include graduated levels of guidance—offer an appealing pathway for fostering meaningful, lasting learning experiences.

Guided discovery learning represents a pedagogical philosophy that prioritizes the learner's active role in constructing knowledge rather than passively receiving information. Kalyani and Rajasekaran [8] highlight the increasing significance of such innovative teaching methods, emphasizing that they help students reach their potential by developing both cognitive flexibility and problem-solving abilities. Similarly, Neber [13] frames discovery learning as a foundational model within the constructivist paradigm, initially conceptualized for formal school settings to facilitate concept formation and understanding through inductive reasoning. This method encourages students to derive principles and abstract relationships from empirical or concrete data, gradually building internalized knowledge structures through guided inquiry.

A central characteristic of guided discovery is its adaptive level of instructional support. The extent of guidance provided is not static but depends on multiple factors: the complexity of the subject matter, learners' prior knowledge, motivation, and their ability to navigate open-ended learning scenarios [4]. This flexibility distinguishes guided discovery from both direct instruction and pure exploratory learning. Holland et al. [5] stress that in such environments, learners must develop organizational frameworks of abstract knowledge by applying personal reasoning strategies to unfamiliar material. The environment must therefore be responsive

to student needs, offering appropriate scaffolds and timely feedback to prevent cognitive overload while maintaining learner autonomy. As Neber [13] notes, these approaches enable students to attain deeper cognitive engagement, supporting the broader educational goal of cultivating higher-order thinking skills, including synthesis, evaluation, and problem transfer.

Various instructional models fall under the umbrella of discovery learning, ranging from learning by examples, to design-based learning, and scientific inquiry. All of these strategies center on student experimentation and exploration as opposed to rote memorization. These practices are especially well suited to digital learning environments, which allow for dynamic content adaptation, interactive feedback, and non-linear progression through educational material. According to De Jong [2], technology-supported inquiry environments are ideal for discovery learning because they can combine scaffolding, real-time analytics, and individualized support in a single platform.

In this regard, computer-based learning ecosystems offer distinct advantages for applying discovery principles at scale. Neber [13] underscores that such environments allow educators to collect granular data on learner activity patterns—such as frequency, task choices, and performance—which can then inform immediate pedagogical decisions. Digital environments can tailor the difficulty level, types of interaction, and pace of progression according to each learner's profile, thereby facilitating a more personalized and effective learning experience. Moreover, game-based learning systems designed around guided discovery principles—such as KIDEDU—incorporate motivational elements like narrative progression, achievement systems, and real-time feedback that enhance engagement and cognitive immersion [9].

Despite these advantages, the Greek educational system has yet to fully embrace discovery-based or digitally mediated teaching approaches. Structural rigidity, traditional attitudes toward instruction, and limited access to educational technology remain substantial barriers. Although policy documents increasingly emphasize student-centered learning and innovation, implementation has lagged behind due to insufficient teacher training and a lack of institutional frameworks to support such initiatives [16]. The few discovery-based interventions that have taken place often remain confined to research settings or experimental classrooms, rather than being scaled across the public education system.

The KIDEDU project, spearheaded by the University of Piraeus, seeks to address this gap by offering a practical and scalable model for integrating guided discovery with differentiated instruction. Through a gamified narrative structure, the platform engages pupils in solving progressively complex challenges related to mathematics and natural sciences. These challenges are designed to match the learners' developmental stage, using scaffolded tasks and varied feedback mechanisms to support understanding. By combining constructivist pedagogy with digital affordances, KIDEDU offers a compelling blueprint for modernizing classroom practice in Greece and beyond. The project not only aims to enhance learning outcomes but also aspires to shift the educational culture toward one that values exploration, adaptability, and learner autonomy.

2 THE KIDEDU PROJECT

2.1 Existing gaming approaches

In recent years, the academic and educational research community has increasingly recognized the value of game-based learning as an effective pedagogical

tool. As a result, considerable resources and scholarly effort have been invested in the creation and assessment of various educational games across different subjects and age groups. However, it is important to highlight that the majority of these existing games are not designed with primary education learners in mind. Moreover, they tend to rely on traditional 2D interfaces and static interaction models, rather than incorporating immersive 3D digital environments.

Given the rapid evolution of digital technologies and the shifting expectations of younger learners, there is a growing need for educational tools that are both technologically advanced and developmentally appropriate. Games that integrate three-dimensional environments, interactive storytelling, and adaptive challenges are far more likely to engage primary school pupils and support the development of abstract reasoning, problem-solving, and mathematical thinking. This gap in the current educational game landscape justifies the development of novel solutions such as KIDEDU, which seeks to combine immersive gameplay with curriculum-aligned content tailored to younger audiences.

2.2 KIDEDU–Play Create Learn

The University of Piraeus has launched the KIDEDU (Play, Create, Learn) initiative as part of an effort to modernize and enrich the way mathematics is taught in Greek primary education. This project introduces a structured series of digital, interactive games specifically designed for children aged 6 to 12. Unlike conventional learning tools, these games incorporate immersive 3D graphics, dynamic animations, and rich sound design to create an engaging, multisensory educational experience. The core aim is to provide an accessible and intellectually stimulating learning environment that moves beyond rote memorization and fosters deep understanding through exploration and interaction.

From a pedagogical standpoint, KIDEDU focuses on cultivating foundational mathematical skills while also introducing pupils to more advanced cognitive concepts. These include basic arithmetic operations as well as introductory principles from graph theory, combinatorial optimization, and decision modeling. The intention is not to overwhelm students with complexity, but to familiarize them with key problem-solving strategies in a playful, age-appropriate context. By incorporating such elements into the game structure, KIDEDU helps young learners gradually develop logical reasoning, pattern recognition, and quantitative thinking.

In addition to its cognitive objectives, the project serves as a direct response to the limitations of traditional teaching methods, which often rely heavily on textbooks, blackboards, and passive learning practices. KIDEDU replaces these outdated tools with a technologically enriched environment that encourages discovery, autonomy, and curiosity—core components of guided discovery learning. The engaging digital setting not only increases student motivation but also provides flexible learning pathways tailored to the pace and preferences of individual users.

The relevance of KIDEDU becomes even more evident when considered through the lens of cognitive learning theory. According to this theoretical framework, learning is triggered when environmental stimuli interact meaningfully with the learner's internal cognitive structures. The richer and more relevant these stimuli are, the more likely it is that learners will retain and transfer knowledge to new contexts. Thus, KIDEDU's game-based structure serves as both stimulus and scaffold, supporting the mental processes necessary for effective concept acquisition. The project's ultimate goal is to provide an educational framework that not only entertains

but also activates core learning mechanisms, enabling pupils to engage deeply with content and gradually acquire more advanced mathematical literacy. In this way, KIDEDU functions as both a pedagogical tool and a cognitive catalyst, aligned closely with contemporary theories of meaningful, learner-centered education.

2.3 Contents of the project

The instruments and concepts of the "Planet Earth" game, in the context of the curriculum for children aged between 6 and 12, involve: Solar System, Planet Earth, Weather and Climate, Water Cycle, Cycle of Rocks, Plants, Evolution of Life, Human Evolution, The Human Body, Ecology and Ecosystems, Greenhouse Effect, Acid Rain and Ozone Hole.

The instruments and concepts of the "Everyday Arithmetic" game include: Addition – Subtraction (number analysis), Multiplication, Division, Length, Weight, Applications, Fractions, Percentages, Factorization, Equations, Corners, Geometric shapes, Solids, Symmetry, Length, Area, Volume, Time, Applications, Money, Applications, Statistics, Applications, Information Management, Complex problems of Mathematics using Informatics and Problems combining Mathematics and Geography.

3 EMPIRICAL RESULTS

Research data was collected from both the questionnaires and the Contractor's personal notes. This data was analyzed and cross-referenced in order to provide evidence relating to the research questions. The most important findings per question are presented in this section.

The initial phase of this research showed that the questionnaire was reasonably well structured, with an average completion time of between 3 and 4 minutes. More specifically:

- Most of the pupils were able to solve the problems of the game and complete the game with ease (Figure 2). Their participation was particularly active and intense, showing enthusiasm during the implementation of the activities (Figures 3 and 6). No particular problems were observed in getting familiar with the game.
- Children's interaction with the application environment was highly engaging, with children quickly reaching high levels of practicality.
- The educational game encouraged pupils to develop various problem-solving strategies, act in a specific environment, control their actions and understand the consequences of their interaction with it, encouraging critical thinking (Figures 4 and 5).
- When solving the problems, the pupils either followed a specific plan of approach to the solution or flexibly adapted to the requirements of each activity.
- Pupils mainly preferred to work in pairs. One child helped and guided the other where this was deemed necessary, thus limiting the role of the teachers.
- The use of images and sound effects played an important role in engaging pupils with the educational game (Figure 1).

Gender: Of the 115 survey participants, 48% were boys and 52% were girls. The gender distribution among participants is relatively balanced, with slightly more girls than boys.

Educational Level: All pupils aged 10–12 years (elementary school pupils).

Use of Technology: 90% (103 out of 115) of the children use a computer or tablet. The large majority of children use a computer or tablet, which shows their familiarity with technology and their ability to effectively interact with the game application.

The following questions are related to the Game Experience: The children's experience during the operation of the game application was assessed through quantitative analysis of the respective responses. The results collected are detailed below:

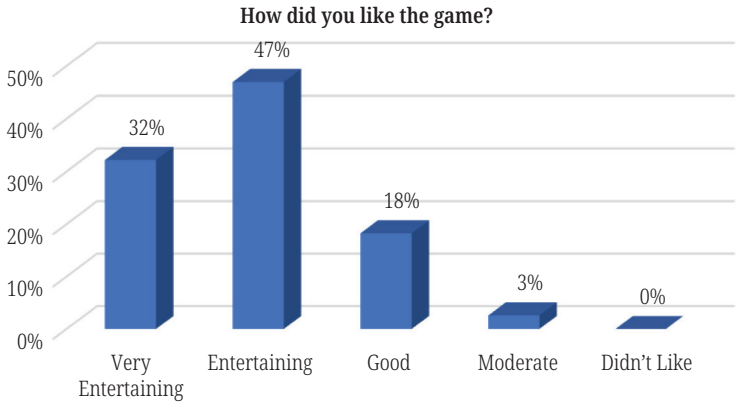

Fig. 1. Game fun

Game Fun: 72% of children rated the game as entertaining or very entertaining.

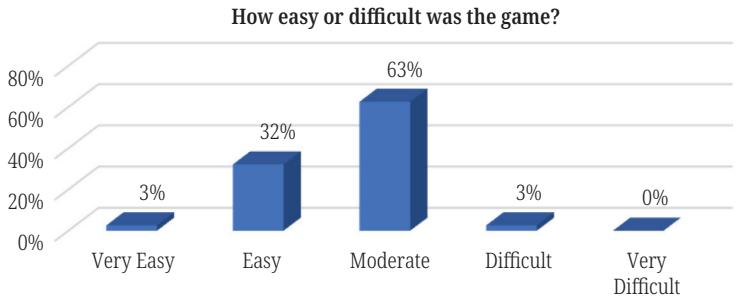

Fig. 2. Game difficulty

Game Difficulty: 86% of children found the game of moderate difficulty or easy.

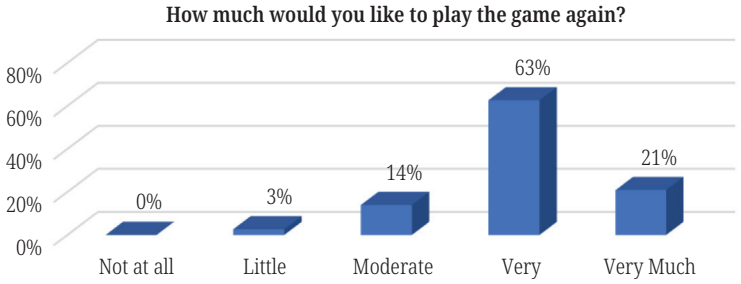

Fig. 3. Willingness to replay

Willingness to Replay: 86% of the participants (willing and very willing) answered that they would play the game again.

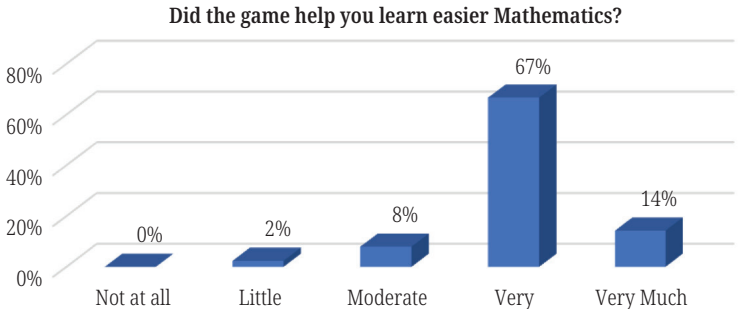

Fig. 4. Easier learning Mathematics

Easier learning Mathematics: 81% of children answered that they learned mathematics easier or much easier playing the game.

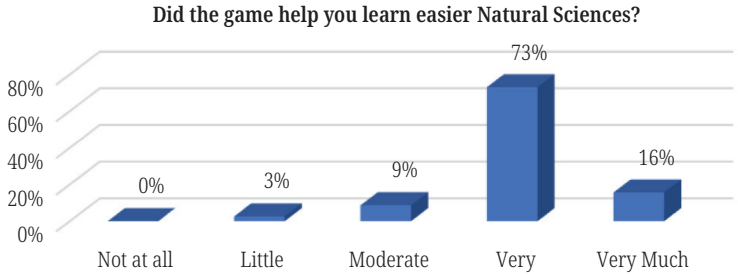

Fig. 5. Easier learning Natural Sciences

Easier learning: 89% of children answered that they learned Natural Sciences easier or much easier playing the game.

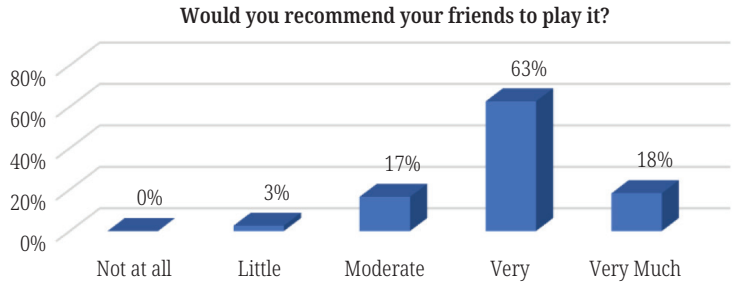

Fig. 6. Recommendation of the game

Game Recommendation: 74% of the participants will recommend the game to their friends.

4 CONCLUSIONS

It is often assumed that individual effort is the primary determinant of academic success. Pupils who dedicate significant time to studying a particular subject area are generally more likely to attain high academic performance. This conventional view has long guided instructional practices in formal education. However, recent research suggests that computer-assisted instruction, particularly when delivered through educational games, can yield outcomes comparable to those of traditional methods—albeit often requiring more development resources [20]. Moreover, findings from more recent studies indicate that computer-based adaptive learning systems may

outperform gamified environments alone, especially for students who demonstrate lower baseline achievement levels or struggle with abstract reasoning [21].

Despite the growing interest in educational technology, the design and implementation of software tailored specifically for pedagogical use remain at an early developmental stage across much of Europe, including Greece. Several obstacles hinder its widespread adoption, such as outdated educational infrastructures, resistance to change within institutional settings, and most critically, insufficient teacher training in the use of emerging digital tools. As a result, even promising innovations face significant barriers when it comes to integration into the national curriculum.

Traditional instructional models have proven effective in ensuring that pupils reach core competency standards within predetermined timeframes. However, these models are often experienced as rigid and uninspiring by learners themselves. Many students express a preference for personalized and interactive learning environments, which in many cases correlate with improved motivation and enhanced performance. While academic literature has yielded mixed conclusions about the impact of technology-assisted instruction—particularly in disciplines such as mathematics and natural sciences the broader trend is clear: technology-enhanced learning is not a temporary phenomenon, but a permanent shift in educational paradigms [17].

Within this evolving landscape, the KIDEDU project represents a forward-thinking and pedagogically grounded initiative that seeks to reshape how knowledge is delivered and absorbed in Greek primary education. By combining principles of guided discovery, game-based learning, and differentiated instruction, KIDEDU introduces an inclusive, learner-centered model of education that aligns closely with contemporary understandings of how children best acquire and retain complex information.

The software developed as part of the project demonstrated a high level of acceptance and enthusiasm among participating pupils, who engaged with the platform in meaningful ways. Its success can be attributed in large part to the thoughtful integration of multimedia features—such as animations, sound effects, and an intuitive virtual assistant—which facilitated seamless interaction and sustained user engagement. Through this enriched digital environment, students were encouraged to explore, hypothesize, and reflect—hallmarks of inquiry-based learning. As a result, participants not only strengthened their academic skills in mathematics and natural sciences but also developed improved perceptual awareness, problem-solving capacity, and intrinsic motivation to learn.

The analysis of the collected data revealed that the KIDEDU educational application has been carefully structured to align with both the physical and cognitive maturity levels of the intended learner groups. Each component of the game—be it the interactive tasks, the narrative flow, or the embedded challenges—has been tailored to reflect the developmental needs of pupils in different age ranges. By calibrating content complexity and visual dynamics to suit learners aged 6–12, the application enables them to acquire knowledge in a way that feels natural, engaging, and developmentally appropriate.

Further examination of the platform's use in classroom settings highlighted its potential to foster interpersonal communication and collaborative learning. The KIDEDU game encourages students to work together, either in pairs or small groups, to solve challenges and share strategies. This promotes the cultivation of key 21st-century skills, including teamwork, critical thinking, and informed decision-making. Moreover, the application offers multiple pathways for self-directed exploration, enabling pupils to search for relevant information, test hypotheses, and engage with content in an active, participatory manner rather than simply consuming information passively.

The implementation of the KIDEDU Game also points toward a broader educational application within the context of non-formal or informal learning. Its structure and flexibility make it well suited for extracurricular programs, home learning environments, or blended learning scenarios. Beyond basic knowledge acquisition, pupils gain meaningful learning experiences that prepare them for real-world challenges and cultivate habits of continuous, self-motivated learning. The app serves not only as a didactic tool but also as a scaffold for lifelong learning competencies, empowering students to apply what they've learned beyond the digital interface.

In summary, the KIDEDU platform stands out as a highly promising educational solution, capable of enhancing the learning process through technology-driven interaction, learner-centered design, and a strong emphasis on skill development. Its adaptability to various learner profiles and its ability to engage children emotionally and intellectually underscore its value as a dynamic and inclusive educational tool.

5 ACKNOWLEDGMENTS

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