CHAPTER-I

CHAPTER I

INTRODUCTION

Game Based Learning is one of the most effective approaches in the present educational scenario. The main focus of Game Based Learning is to motivate and improve the attitude of students in the learning system (Rajan, 2022). Game Based Learning (GBL) has emerged as a dynamic pedagogical approach that integrates game elements into educational settings to enhance student engagement and learning outcomes. Recent studies have highlighted its effectiveness in various disciplines, demonstrating positive impacts on motivation, academic performance, and reflective thinking skills.

In the past few decades, Game Based Learning (GBL) has gained recognition as an effective medium for attaining educational purposes. It has been observed that games offer experiential learning and are reflective in nature, making them the ideal medium to integrate reflective learning. An assuring direction for supporting students' reflection is Game Based Learning. The noble concepts of serious games, Game Based Learning (GBL), e-learning, and gamification have gathered significant attention in both academic and edutainment domains over the past decade **(**Martens and Müller, 2017).

Game Based Learning is quite an active instructional approach that integrates game characteristics, gamification, learning goals, and pedagogical methods into educational activities. The "play" element in Game Based Learning is crucial, as it enables learners to connect and interpret their physical and social environments, fostering meaningful learning interactions (Gee, 2004). Game Based Learning refers to an educational approach where games (digital or analogue) are used in order to engage students in interactive and immersive experiences designed to teach specific concepts, skills or subjects and inculcate values through reflection. Gamification refers to the implementation of game design elements, such as point systems, rewards and competition. Game elements as well as mechanics and structures, when incorporated into the learning process, can enhance student understanding and increase engagement, motivation and retention of educational content as well as moral integration.

In the field of education and research, Game Based Learning (GBL) has emerged as a transformative approach, particularly effective in fostering critical thinking and reflective abilities among students. By immersing learners in interactive scenarios, GBL encourages them to analyze situations, make decisions, and reflect on outcomes, thereby enhancing their cognitive skills. This method is especially beneficial in subjects like Biology, where complex concepts and systems require deep understanding and analytical thinking.

In the realm of Biology education, GBL offers students the opportunity to engage with intricate biological processes through simulations and interactive modules. For instance, the BioScientist digital game is designed to develop inquiry skills in eighth-grade students by guiding them through tasks related to the skin, musculoskeletal system, and other biological topics. Such games not only make learning more engaging but also promote a deeper understanding of the subject matter by allowing students to experiment and observe outcomes in a virtual environment. Moreover, GBL supports the development of reflective thinking by providing immediate feedback and opportunities for students to assess their decisions. Games like Genomics Digital Lab enable learners to explore cellular processes and understand the consequences of their actions within the game. This reflective practice helps students internalize concepts and apply their knowledge to new situations, fostering a more profound and lasting comprehension of biological principles (Drogaris, 2023).

The adaptability of GBL also allows for personalized learning experiences, catering to diverse learning styles and paces. By adjusting difficulty levels and providing various pathways to problem-solving, educational games can meet individual student needs, making subjects like Biology more accessible and less intimidating. This personalized approach not only boosts confidence but also encourages a growth mindset, where students view challenges as opportunities to learn and improve. Integrating Game Based Learning into Biology education offers a multifaceted approach to teaching that enhances critical and reflective thinking. By making learning interactive, personalized, and reflective, GBL addresses the challenges of teaching complex scientific concepts and prepares students to think analytically and adaptively. As educational technologies continue to evolve, the role of GBL in fostering essential cognitive skills, in particular reflective skills in subjects like Biology is likely to become increasingly significant.

1.1 Background of the Study

Over the past few years, educators have been increasingly drawn to innovative teaching methods that go beyond the traditional classroom setup: especially in subjects like Biology, where understanding complex concepts is key. Conventional lecture based teaching often falls short in keeping students actively engaged or encouraging them to think deeply about what they're learning. In contrast, Game Based Learning (GBL) has emerged as a promising alternative, offering a more interactive and student-centered experience. By integrating games into the learning process, students are not only more motivated but also encouraged to think critically, make decisions, and reflect on their actions—skills that are crucial for deeper understanding. This becomes even more important at the middle school level, where students are developing the ability to think more abstractly. Given this, there's a growing need to explore how Game Based Learning can influence students' reflective thinking skills, especially in a subject like Biology that requires both conceptual understanding and the ability to apply knowledge thoughtfully. This study aims to investigate whether using game-based strategies can make a measurable difference in how middle stage students reflect, understand, and engage with biological content.

The evolution of educational practices has long reflected shifts in societal needs, cognitive theories, and technological advancements. Traditionally, Biology instruction at the middle stage level followed a rigid, teacher-centered approach rooted in rote memorization and passive absorption of facts. This model, dominant throughout much of the 20th century, was largely influenced by behaviorist theories, which emphasized repetition and reinforcement. However, by the late 20th and early 21st centuries, educational thought began to shift toward constructivist and experiential learning paradigms, highlighting the importance of active engagement, student autonomy, and higher-order thinking skills. Reflective thinking — the ability to analyze, evaluate, and synthesize knowledge — began to emerge as a crucial educational goal, especially in science education. Game Based Learning, though once considered informal or supplementary, gradually gained academic credibility as researchers and educators observed its potential to support both cognitive development and learner motivation. Over time, GBL has evolved from simple classroom games to complex, technology-enhanced platforms designed to stimulate curiosity, reflection, and meaningful learning—especially in concept-heavy subjects like Biology.

Looking ahead, the role of technology-driven education is expected to grow even more prominent, with Game Based Learning at the forefront of this evolution. As artificial intelligence, virtual reality (VR), and augmented reality (AR) become more accessible in classroom settings, the potential to create immersive, personalized, and adaptive learning environments is rapidly expanding. These tools can simulate complex biological systems, allowing students to experiment, visualize, and reflect in ways traditional methods cannot offer. In the future, educational games may not only respond to students' choices but also analyze their thinking patterns in real-time, offering tailored feedback that promotes deeper reflection and understanding. For middle stage students; who are at a pivotal developmental phase—such innovations could bridge the gap between curiosity and comprehension, transforming the way Biology is taught and learned. By fostering reflective thinking through these advanced tools, educators can prepare students not just for exams, but for a future where critical thinking, problem-solving, and adaptability is essential.

1.2 Historical background of Game Based Learning

Game Based Learning (GBL) has a rich and diverse history, evolving from ancient educational practices to modern digital applications. Historically, games have been utilized as educational tools for thousands of years, aiding in the development of strategic thinking, language skills, and mathematical understanding. In ancient civilizations such as Greece and Rome, play based learning was an integral part of education. Board games like Chess and Mancala, dating back over 5,000 years, were employed to teach logic and combinatory skills (Hellerstedt, 2019). The 20th century saw a formalization of educational games, with the introduction of paper-based games in the 1960s and 1970s. However, the "Back to Basics" movement led to a decline in their popularity. The term "serious games" was coined by Clark C. Abt in the 1970s, which referred to games designed with explicit educational purposes.

The advent of digital technology revolutionized GBL. In 1964, "The Sumerian Game" became one of the first educational video games designed for elementary students. The 1980s witnessed a surge in educational software, partly due to the video game crash of 1983, which shifted focus towards educational content in the home computer market.

In contemporary education, GBL continues to evolve, integrating advanced technologies and pedagogical strategies. Recent studies have explored the effectiveness of GBL in teaching highlighting the potential of games to enhance student engagement and learning outcomes (Hellerstedt, 2019).

Several prominent global initiatives that integrate Game Based Learning (GBL) to enhance reflective thinking in Biology education are:

- The GLOBE Program (Global Learning and Observations to Benefit the Environment); established in 1994 and active in over 125 countries is a hands-on science and education initiative focusing on environmental studies. It engages students in collecting and analyzing real-world data related to the atmosphere, biosphere, hydrosphere, and pedosphere. Through collaborative research with scientists, students develop critical thinking and reflective skills by connecting their observations to global environmental patterns.
- PhET Interactive Simulations; developed by the University of Colorado Boulder, offers over 125 free interactive simulations in subjects including Biology. These simulations allow students to explore complex biological concepts through virtual experiments, promoting inquiry-based learning and reflection on scientific phenomena.
- Quest Atlantis / Atlantis Remixed, is an educational game that combines narrative, role-play, and problem-solving to teach subjects like science and social studies. Students engage in quests that require them to apply scientific knowledge to real-world issues, fostering reflective thinking and ethical reasoning.
- International Biology Olympiad (IBO) is a prestigious competition that brings together top pre-university Biology students from over 75 countries. Participants engage in challenging theoretical and practical exams, encouraging deep understanding and reflection on biological concepts. The competition also includes collaborative projects that promote international scientific discourse.
- Bioblox 2.5D is an educational game developed collaboratively by Goldsmiths, University of London, and Imperial College London. The game focuses on protein docking, allowing students to explore Molecular Biology concepts.

- BIG GAME Project; co-funded by the European Commission under the Erasmus Plus program, the BIG GAME project integrates cooperative, story-driven digital games into STEM education. Implemented across Romania, Italy, Estonia, and Finland, the project has shown significant improvements in students' transversal skills, including critical thinking and reflection, through environmental problem-solving missions.

Game Based Learning (GBL) in India has evolved by integrating traditional educational practices with modern technological advancements. In ancient India, Game Based Learning was deeply intertwined with cultural, philosophical, and educational practices. Traditional games served not merely as entertainment but as tools for imparting moral values, strategic thinking, and social skills. Games like *Gyan Chauper* (the precursor to modern Snakes and Ladders) and *Leela* were designed to teach players about virtues, vices, and the path to spiritual enlightenment. Each square on the board represented moral choices and their consequences, guiding players through lessons on dharma (duty), karma (action), and moksha (liberation). *Chaturanga*, considered the ancestor of modern chess, was a game that emphasized strategic planning and foresight. Played on an 8x8 board, it mirrored the complexities of warfare and governance, reflecting the societal emphasis on tactical acumen. Games like *Pallankuzhi* (a variant of Mancala) were popular in South India and involved counting and strategic distribution of seeds or shells across pits on a board. Such games enhanced arithmetic skills and logical reasoning among players. Traditional sports such as Kho-Kho and Kabaddi were integral to physical training, promoting agility, coordination, and team spirit. These games were often linked to martial training and community bonding (Solanki, 2023). Several traditional games aimed to foster an understanding of biological concepts, such as animal behavior, ecological relationships, and physical development. Bagh-Chal; a strategic board game being predator-prey dynamic mirrors ecological relationships, introduced players to concepts of food chains and animal behavior. A traditional South Indian mancala game, Pallanguzhi; played on a board with fourteen pits involves distributing seeds or shells. While primarily enhancing arithmetic skills, the use of seed leads to discussions about Plant Biology, seed types, and agricultural practices (Solanki, 2022).

Later, India's educational system emphasized rote memorization, but recent initiatives have shifted towards more interactive and engaging methods.

1.3 Government initiatives driving Game Based Learning in education

The National Education Policy (NEP) 2020 underscores the importance of experiential and play based learning, leading to programs like the Bharatiya Khel initiative under the Indian Knowledge System (IKS), reintroducing 75 traditional Indian games into school curricula to promote holistic development and experiential learning.

Technological integration has further propelled GBL in India. Platforms such as BYJU'S, Quizizz, and PlayAblo have incorporated gamified elements into their educational content, enhancing student engagement and learning outcomes. Additionally, initiatives like the Sampark Smart Shala program have transformed government schools into smart learning environments by providing digital tools and training to educators. These developments reflect a broader trend in Indian education towards embracing innovative teaching methodologies that combine traditional values with modern technology to create more effective and engaging learning experiences.

India has initiated several programs and educational models that integrate Game Based Learning (GBL) to enhance reflective thinking, particularly in Biology and STEM education.

- CUBE (Collaboratively Understanding Biology Education) by Kishore Bharati promotes inquiry-driven Biology education through student-led research projects. Students engage in hands-on experiments with model organisms like earthworms and hydra, fostering reflective thinking and scientific inquiry. The program emphasizes collaborative learning and connects projects to the school curriculum, enhancing relevance and engagement.
- SynBio Spark by IISER Tirupati (iGEM 2023); an outreach initiative introduces students to synthetic Biology through interactive sessions and hands-on activities. By aligning content with existing curricula and encouraging student feedback, SynBio Spark fosters critical thinking and reflective learning in Biology.

- Agastya International Foundation, operates mobile science labs and centers across India, providing experiential learning opportunities in science and Biology. Through hands-on experiments and peer-led instruction, students develop curiosity, critical thinking, and reflective skills.
- REC Chennai team developed interactive games like "Heads-Up" and "CO_2 vs. Ship" to educate the public on synthetic Biology and climate change. These games encourage participants to think critically and reflect on scientific concepts in an engaging manner.
- Innovative Pedagogies at PM SHRI Kendriya Vidyalayas (Kendriya Vidyalaya Ballygunge and Banswara) have adopted innovative teaching methods, including inquiry-based learning, storytelling, and project-based learning. These approaches encourage students to explore biological concepts actively, fostering reflective thinking and deeper understanding.

These programs collectively aim to shift education from rote memorization to a more engaging, reflective, and inquiry-based approach, particularly in the field of Biology.

1.4 Game Based Learning and Reflective Thinking

Reflection, a cycle of "thinking and doing" (Donald A Schön, 1983), is a crucial component as well as a critical aspect of the learning process. According to American philosopher John Dewey, meaningful experiences are not possible without some element of reflection (Dewey, 1933). Reflective thinking is an essential forerunner to develop higher-order thinking skills which facilitates effective problem-solving; a must need expertise for puzzling out 21st century global enigmas. Over the past few years, reflective learning has gained popularity as an effective form of education that involves students reflecting on their past experiences to enhance their deftness and learning.

Reflective thinking is an important component of 21st-century education, enabling learners to critically analyze experiences, integrate knowledge, and apply insights to novel situations. Game Based Learning (GBL), characterized by the incorporation of game elements into educational contexts, has emerged as a promising approach to foster reflective thinking.

In the past few decades, Game Based Learning (GBL) have gained recognition as an effective medium for attaining educational purposes. It has been observed that games offer experiential learning and are reflective in nature, making them the ideal medium to integrate reflective learning. An assuring direction for supporting students' reflection is Game Based Learning**.** Khaled (2018) has published her work explaining the game elements that are suitable to support reflective thinking in games and quoted, *"Games are reflection machines"*. The Reflective Game Design (RGD) framework (Shaheen et al., 2022) represents a more recent model that emphasizes the amplification of learning through reflective observation and authentic feedback.

GBL leverages the engaging nature of games to create immersive learning experiences. Reflective thinking within GBL involves learners analyzing their gameplay experiences, decision-making processes, and outcomes to derive meaningful insights. The integration of reflection into GBL is crucial for deep learning and the development of higher-order cognitive skills.

Various findings suggest that integrating reflective elements into Game Based Learning can significantly enhance students' reflective thinking skills, leading to improved learning experiences and cognitive development.

1.5 NEP 2020 on Reflective skill enhancement through GBL at Middle stage

In India, the New Education Policy (NEP) 2020 marks a fundamental shift and advocates replacing rote learning with innovative and experiential methods, such as gamification and applications that can deliver high-quality education mentioning, "In all stages, experiential learning will be adopted, including hands-on learning, arts-integrated and sports-integrated education, story-telling-based pedagogy, among others, as standard pedagogy within each subject, and with explorations of relations among different subjects" (NEP 2020, 4.6). The integration of GBL into middle-stage Biology education in India aligns closely with the objectives of the National Education Policy (NEP) 2020, which emphasizes experiential, activity-based, and student-centered pedagogies. NEP 2020 prioritizes middle stage curriculum and advocates for projects, practical and enhancing critical thinking skills. During the three-year phase, students in grades six through eight would delve further into the subject matter. It is noted that the Middle Stage would allow students to examine subjects more deeply, facilitating

critical thinking. Additionally, the Middle Stage focused on integrating project-based learning so that students could gain practical experience. NEP 2020 advocates the Curriculum content to be reduced in each subject to its core essentials, to make space for critical thinking and more holistic, inquiry-based, discovery-based, discussion-based, and analysis-based learning (NEP 2020, 4.5). It says, “Teaching and learning will be conducted in a more interactive manner; questions will be encouraged, and classroom sessions will regularly contain more fun, creative, collaborative, and exploratory activities for students for deeper and more experiential learning.” (NEP 2020, 4.5).

NEP 2020 restructures the school education system into a 5+3+3+4 model, with the middle stage (Grades VI–VIII) focusing on experiential learning across subjects, including sciences. This approach encourages the use of interactive methods such as games to make learning more engaging and effective. Several initiatives like Cambrionics Life Science and ChemAmaze Programme have been undertaken to incorporate GBL into Biology education. The adoption of Game Based Learning in middle-stage Biology education reflects NEP 2020's vision of transforming education through innovative, student-centered approaches. By making learning more interactive and culturally relevant, GBL contributes to developing critical 21st century skills among students.

1.6 NCF-SE 2023 and GBL

The National Curriculum Framework for School Education (NCF-SE) 2023, developed under the guidance of the National Education Policy (NEP) 2020, emphasizes experiential, activity-based, and student-centered pedagogies. This framework aligns with the integration of Game Based Learning (GBL) into middle-stage Biology education in India, aiming to enhance student engagement, motivation, and conceptual understanding. NCF-SE 2023 has Implemented some of the Game Based Learning Initiatives such as:

- Cambrionics Life Science: This educational enterprise engages middle and high school students in curiosity-driven Biology learning experiences beyond textbooks, utilizing research-based models.

- ChemAmaze Programme: Developed in collaboration with BASF Chemicals India Pvt. Ltd., this program has created 88 games for Grades VI to VIII, conducted 12 workshops nationwide, and trained over 1,200 teachers. The games are designed to be accessible, with translations into vernacular languages and adaptations for low-literacy contexts.
- Bharatiya Khel Initiative: Under NEP 2020 and the Indian Knowledge System (IKS) Division, this initiative introduces 75 traditional Indian games into schools to promote teamwork, creativity, and cultural heritage.

The use of Game Based Learning in middle-stage Biology classrooms lines up with the vision set out in the NCF-SE 2023, which emphasizes the shift toward more engaging, student-focused education. By making lessons interactive and connecting them with real-life and cultural contexts, Game Based Learning helps nurture essential skills such as critical thinking, creativity, and collaboration among students.

1.7 Role of Biological Science as a reflective subject at Middle stage

Biology is everywhere. Students need to reflect on it. Biology permeates our daily lives—from news reports on pandemics to the flora in our surroundings. This omnipresence underscores the importance of helping students connect classroom learning with real-world experiences. By encouraging students to relate their studies to everyday phenomena, educators can make science more engaging and relevant. Such connections not only enhance understanding but also promote reflective thinking, enabling students to appreciate the significance of biological concepts in their lives. Integrating social issues and historical contexts into Biology education further enriches this learning experience, fostering a deeper comprehension and appreciation of the subject. By encouraging students to find connections between their studies and everyday experiences, science becomes more engaging and relevant (Chamany. K et, al., 2008). Biology, as a reflective subject, offers students a unique opportunity to engage deeply with the natural world, fostering critical thinking and self-awareness. Through the study of living systems, students are encouraged to observe, analyze, and question, leading to a deeper understanding of both scientific concepts and their own learning processes. Reflective practices in Biology education, such as journaling and self-assessment, enable students to connect theoretical knowledge with real-life experiences, promoting metacognition and self-regulated learning.

This approach not only aids in academic achievement but also prepares students to make informed decisions about health, environment, and ethical issues, contributing to their overall personal growth and societal awareness. Incorporating reflective learning in Biology aligns with educational frameworks that emphasize experiential and inquiry-based learning, ensuring that students develop the skills necessary to navigate and contribute to an increasingly complex world.

Middle stage students of age group twelve to fourteen mark their emergence in early adolescence phase. Adolescence is a pivotal stage marked by significant cognitive, emotional, and social development. During this period, individuals transition from concrete to abstract thinking, enabling them to analyze complex concepts and reflect on their learning processes. Biology, as a subject, offers adolescents the opportunity to explore intricate systems and phenomena, fostering critical thinking and self-awareness. Engaging with biological concepts encourages students to question, hypothesize, and draw connections between theoretical knowledge and real-world applications. This reflective engagement not only enhances their understanding of the subject but also promotes metacognitive skills essential for lifelong learning. By integrating reflective practices into Biology education, educators can support adolescents in developing a deeper comprehension of scientific principles and their relevance to everyday life.

1.8 Recent transformation of Biology Teaching at Middle school education

Biological Science education plays a critical role in equipping human resources to face the increasingly complex challenges and demands of life in the 21st century (Ramadhanti et, al., 2022). Knowledge delivered through games has a profound effect on the younger generation in every aspect, such as their mind, physical appearance, and behavior (Amdan and Salleh, 2016).

Biology education at the middle school level has undergone significant transformation. Driven by technological advancements, pedagogical innovations, and an increased emphasis on environmental sustainability, educators are adopting diverse strategies to enhance student engagement and understanding. A prominent shift in Biology education is the move towards active, student-centered learning approaches. Inquiry-based learning (IBL) encourages students to engage in scientific processes by posing questions, designing experiments, and analyzing data.

The 5E instructional model; Engage, Explore, Explain, Elaborate, Evaluate-has been widely adopted to structure these learning experiences, fostering critical thinking and deeper understanding (Bui, 2024 and Jumma, 2023).

Incorporating real-world problems into the curriculum has also proven effective. Problem-based learning (PBL) strategies have been shown to enhance student motivation and achievement in Biology by connecting classroom content to students' lives and communities (Roehrig, 2022). Technological integration has become a cornerstone of modern Biology education. Virtual field trips (VFTs) offer students immersive experiences, allowing them to explore diverse ecosystems and biological phenomena without leaving the classroom. These digital excursions have been linked to increased student engagement and improved comprehension of complex biological concepts (Bennett, 2019). Virtual Reality (VR) has also been employed to simulate laboratory experiments, providing students with interactive and safe environments to explore biological processes. Studies indicate that VR-based instruction can enhance long-term retention and foster a deeper sense of immersion in the subject matter (Taman, 2023).

Interdisciplinary teaching methods have gained traction, integrating Biology with subjects like technology, engineering, and mathematics. Project-based learning (PjBL) initiatives encourage students to apply biological knowledge to real-world challenges, promoting critical thinking and problem-solving skills. For instance, designing technical toys or conducting environmental projects allows students to experience the practical applications of Biology (Roehrig, 2022).

Educators are increasingly incorporating sustainability and environmental education into Biology curricula. Outdoor learning experiences, such as visits to nature parks and botanical gardens, provide students with firsthand exposure to ecological systems, fostering a deeper appreciation for biodiversity and conservation efforts (Palmberg, 2000). These authentic learning environments have been shown to improve student outcomes and encourage adaptive learning strategies, including critical thinking and organization.

Bio literacy—the ability to understand and engage with biological topics—has become a focal point in middle-stage education. Citizen science initiatives, such as iNaturalist, involve students in real-world data collection and ecological monitoring, enhancing their understanding of biodiversity and scientific inquiry (Hitchcock, 2021).

Biology and evolutionary concepts have significantly influenced the development of various video games, including Spore, Plague Inc., Cell to Singularity, and Niche. These games have inspired innovative approaches to teaching Biology through interactive digital platforms. Educational games such as Immune Attack, Immune Defense, Tyto Online, and Genomics Digital Lab have been specifically designed to enhance students' understanding of biological concepts by allowing them to engage with the material actively (Drogaris, 2023).

Furthermore, there is a shift from traditional assessment methods towards more formative and supportive evaluation practices. Emphasizing student participation and feedback, these approaches aim to create emotionally supportive learning environments that encourage adaptive learning strategies. The contemporary period has witnessed significant advancements in the teaching of Biology at the middle school level. By embracing active learning, technological integration, interdisciplinary approaches, and a focus on environmental sustainability, educators are better equipped to engage students and foster a deeper understanding of biological sciences. These innovations not only enhance academic achievement but also prepare students to navigate and contribute to an increasingly complex and interconnected world.

1.9 Impact of GBL integrated Biology Education

Integrating games into Biology education for middle-stage students has proven to be an effective strategy for enhancing engagement, motivation, and conceptual understanding, both in India and internationally. The integration of Game Based Learning (GBL) into Biology education has shown promising results in enhancing students' reflective thinking and critical inquiry skills. By engaging students in interactive and immersive learning environments, GBL facilitates deeper understanding of complex biological concepts and promotes active learning.

One notable example is the "BioScientist" digital game, designed to develop inquiry skills aligned with the biology curriculum. The game incorporates pedagogical content with engaging game elements, such as structured tasks and contextualized feedback, to support students in performing scientific inquiries (Erdemir, N., & Uyanik, G. K.,2024). Reflective thinking, a critical component of meaningful learning, is also supported through GBL. Research has shown that incorporating reflection prompts within games or guided instructor-led reflections can facilitate students' understanding and retention of scientific concepts. These reflective practices encourage students to connect gameplay experiences with underlying biological principles, enhancing their overall learning experience (Yang, X., & Liu, Y., 2021).

Furthermore, GBL has been found to improve various student abilities, including critical thinking, activeness, independence, and cognitive learning outcomes. Implementations of GBL in Biology education, such as web-based games and traditional games like crosswords, have contributed positively to students' concept understanding and engagement. The correlation between Biology education, reflective thinking, and Game Based Learning is evident through various studies and implementations. By leveraging the interactive nature of games, educators can foster an environment that promotes critical inquiry and reflective learning, ultimately enhancing students' comprehension and appreciation of biological sciences.

Additionally, there is a need for deeper exploration into how reflection is defined within the context of educational games, how it can be effectively supported across different subject areas, and what existing game features actually encourage students to engage in reflective thinking.

1.10 Rationale of the Study

Game Based Learning is essential for the 2^{1st} century because it harnesses the engaging power of games to enhance education and skill development. In a world where practical aspects, experiential learning and empirical knowledge are paramount, Game Based Learning offers interactive and immersive experiences that cater to diverse learning styles, promoting critical thinking, problem-solving, and collaboration skills among students. The objective of GBL is to transform the learning process into an enjoyable experience, fostering motivation, engagement, and active participation.

These games often incorporate real-world scenarios, allowing students to apply knowledge in meaningful contexts. Additionally, the motivation and enjoyment derived from gameplay can foster a love for learning, encouraging students to take risks and explore new concepts. As the workforce increasingly demands adaptability and innovative thinking, Game Based Learning equips learners with the skills necessary to thrive in an ever-evolving landscape.

Reflective thinking is essential for success in unpredictable and complex situations. It helps to develop a questioning attitude and new perspectives, identify areas for change and improvement, respond effectively to new challenges and generalize and apply what one has learned from one situation to other situations. Reflective thinking skills are very important in the learning process because the reflection activities carried out can help students develop their own thinking (Dewi & Erman, 2021). Reflective thinking skills are one of the five high-level thinking skills in twenty-first-century learning. The process of reflective thinking is crucial, especially in science education. Mastering reflective thinking skills helps students in solving scientific problems using scientific methods (Mustafid et al., 2024).

This critical self-examination encourages learners to evaluate their assumptions, explore alternative perspectives, and integrate new knowledge, ultimately fostering personal and professional growth. Reflective thinking is essential for continuous learning and improvement, allowing individuals to adapt and evolve in various worldly contexts. Teacher-centered Biology teaching method such as lecture method and rote memorization involves passive learning where teacher acts as the only source of knowledge and students are inactive participants. This single-way communication method has been found less effective in comparison to game-based Biology teaching where games are integrated element of learning to have a fun way learning with proper reflection.

Traditional methods of teaching Biology in middle schools often face challenges in capturing and sustaining students' interest as well as reflection. Game Based Learning presents an opportunity to address this issue by tapping into the natural affinity that students have for interactive and enjoyable experiences.

Incorporating gaming into the middle school Biology curriculum offers a transformative approach by addressing the unique challenges of teaching complex biological concepts and promoting students' reflection. By adapting gaming experiences to the intricacies of Biology, educators can enhance student engagement, promote reflective thinking, and provide a dynamic learning environment that aligns with the specific demands of biological education in middle schools. Initiating reflection or enhancing reflective thinking in science subjects specially in biological sciences of senior secondary level is a must need approach to create critical awareness about own body as well as environment of students. There are many research works in this area but particularly in some specific topic like reproduction Biology, puberty and adolescence introductory chapters, more work is needed to be done. As these kinds of topics are still less talked and less focused in many schools due to its sensitivity. More clarity and reflection are still lacking among students. Students of content-rich subjects such as Biology are prone to memorizing instead of learning by thorough comprehension. When learning such subject matter, students simply memorize the knowledge without processing it; thus, this knowledge is quickly forgotten. It has been observed that one common problem encountered by the students in the biological sciences is difficulty in understanding biological concepts. Many students become discouraged by the course because of the complex vocabulary. Traditional teaching is a teacher-centered method carried out without any interaction between the teacher and students or among students themselves, and generally leads to boring and ineffective lessons. Thus, there is a great need of introducing various new teaching methods to enhance active student participation to make teaching-learning fruitful. Game based teaching has been highlighted in this new era of NEP 2020 as well as NCF-SE 2023.

The need for studies examining the effectiveness of Game Based Learning (GBL) on reflective thinking among middle-stage Biology students in India is underscored by the evolving educational landscape that emphasizes experiential and student-centered learning. Reflective thinking is integral to deep learning, enabling students to analyze their experiences and enhance understanding. Biology, with its complex systems, offers an ideal context for implementing GBL strategies that foster such reflective practices. Recent studies have highlighted the potential of GBL in enhancing cognitive skills and promoting reflective thinking among students.

Despite the recognized benefits of GBL, there remains a gap in empirical research specifically examining its impact on reflective thinking in middle-stage Biology education within the Indian educational framework. Addressing this gap is crucial for developing effective teaching strategies that not only engage students but also cultivate critical thinking skills essential for their academic and personal growth. Therefore, this study aims to explore the effectiveness of Game Based Learning in fostering reflective thinking among middle-stage students in Biology, contributing valuable insights to educators and policymakers striving to enhance science education through innovative pedagogical practices.

The rationale for exploring the effectiveness of Game Based Learning (GBL) on reflective thinking among middle-stage students in Biology stems from the evolving educational paradigms that prioritize experiential and student-centered learning. Reflective thinking is integral to deep learning, enabling students to analyze their experiences and enhance understanding. Biology, with its complex systems, offers an ideal context for implementing GBL strategies that foster such reflective practices. Recent studies have highlighted the potential of GBL in enhancing cognitive skills and promoting reflective thinking among students. For instance, Shaheen and Fotaris (2023) discuss how digital games can serve as "reflection machines," naturally encouraging learners to think critically about their actions and decisions within the game environment. Similarly, a meta-analytic review by Chen et al. (2023) indicates that digital educational games are effective in developing higher-order cognitive skills, which are essential for reflective thinking.

In the context of Biology education, traditional teaching methods often delay the introduction of complex concepts like cellular processes, genetics, or ecological interactions until students reach higher grade levels, based on assumptions about developmental readiness. However, recent cognitive research suggests that students possess intuitive understandings of these biological phenomena even before formal instruction. This insight opens avenues for introducing such concepts earlier through developmentally appropriate methods, such as Game Based Learning (GBL). GBL leverages interactive and engaging platforms to present biological concepts in a manner that aligns with students' natural curiosity and cognitive abilities.

By simulating real-life biological scenarios, games can facilitate early exposure to complex topics, allowing students to explore and internalize concepts through experiential learning. Moreover, GBL fosters reflective thinking by encouraging students to analyze outcomes, make decisions, and understand the consequences of their actions within the game environment. This reflective practice is crucial in Biology, where understanding the interconnectedness of systems and the impact of variables is essential. Through gameplay, students develop critical thinking skills, enhancing their ability to comprehend and apply biological concepts effectively. Early intervention using GBL in Biology education can also address disparities in student achievement. By engaging students at a younger age with interactive and thought-provoking content, educators can bridge gaps in understanding and foster a more inclusive learning environment. This proactive approach can mitigate long-term educational disparities, promoting equity in science education. Integrating Game Based Learning into early Biology education capitalizes on students' inherent abilities and interests, providing a platform for the early introduction of complex concepts. By promoting reflective thinking and critical analysis, GBL not only enhances comprehension but also prepares students for future scientific endeavors.

Research into the impact of Game Based Learning (GBL) on the reflective thinking skills of early adolescents in Biology education is both timely and significant, addressing the evolving needs of learners in the 21st century. Early adolescence, typically encompassing ages 12 to 15, is a critical period marked by significant cognitive development and heightened neural plasticity. During this stage, students are particularly receptive to learning experiences that are interactive and engaging. GBL leverages this developmental window thereby enhancing learning outcomes. Such interactive experiences are especially beneficial in subjects like Biology, where abstract concepts can be made more tangible through simulation and gameplay.

Reflective thinking involves the ability to analyze one's learning processes and outcomes critically. GBL fosters this by encouraging students to make decisions, observe consequences, and adjust strategies within a game context. This iterative process mirrors scientific inquiry, promoting deeper understanding and metacognitive skills essential for mastering complex biological concepts. Biology often presents challenges due to its intricate systems and processes.

Traditional teaching methods may not adequately engage students or convey the dynamic nature of biological phenomena. GBL addresses this by providing interactive simulations that allow students to experiment with biological systems, observe outcomes, and develop a more profound understanding of the subject matter. GBL can cater to diverse learning styles and needs, offering personalized learning experiences that can bridge achievement gaps. By adapting to individual learners' pace and providing immediate feedback, GBL ensures that all students, regardless of their background, have the opportunity to develop reflective thinking skills and achieve academic success in Biology. Modern education emphasizes the development of critical thinking, problem-solving, and lifelong learning skills. GBL aligns with these goals by creating learning environments that are student-centered, inquiry-based, and reflective. Incorporating GBL into Biology education not only enhances content understanding but also prepares students to navigate complex real-world problems. Investigating the effects of GBL on reflective thinking in early adolescent Biology education is justified by its potential to enhance cognitive development, address educational challenges, promote equity, and align with contemporary educational objectives.

1.11 Statement of the Problem

The following study is worded as "**A STUDY ON EFFECTIVENESS OF GAME BASED LEARNING ON REFLECTIVE THINKING OF MIDDLE STAGE STUDENTS IN BIOLOGY**"

1.12 Operational Definition of the Key Terms

Game Based Learning (GBL)- refers to an educational approach where games are used in order to engage students in interactive and collaborative manner to teach specific concepts, skills or subjects and inculcate values through reflection. Here in this research a self-developed Reflective card game has been used which is well-structured by explicit rules and teamed-activities for enhancement of reflective thinking and improvement of clarity in biological concepts.

Traditional method of teaching- This is lecture method; a teacher centered teaching method, based on behaviorist approach where instructor delivers information to a group of students through spoken discourse.

Achievement in Biology- Academic score in Biological Science Achievement Test (BSAT) will be considered as learner's achievement in Biology.

Reflective thinking level-Reflective thinking levels denote the depth at which individuals analyze their experiences to inform future actions. This progression typically begins with descriptive reflection, where one recounts events without analysis. It advances to analytical reflection, involving examination of reasons and outcomes, and culminates in critical reflection. These levels facilitate deeper learning and informed decision-making. Here Reflective thinking level has been assessed on the basis of Item-wise mean scores of RTIESS (Reflective Thinking Instrument for Elementary School Students).

Effectiveness- In this study, effectiveness is described as a significant difference between mean academic scores of experimental group over the control group in post-test in terms of students' academic score in Biological Science Achievement Test (BSAT), difference between level of reflective thinking based on Item-wise mean scores of RTIESS and attitude towards GBL.

Middle stage students- It refers to students aged between 12-14 years of age who are studying in CBSE affiliated Govt. Senior Secondary School.

1.13 Objectives of the Study

1) To study the effectiveness of Game Based Learning on reflective thinking of middle stage students in Biology.
2) To compare the mean academic scores of experimental group over the control group students exposed to Game Based Learning with those taught through traditional lecture methods of teaching.
3) To study the attitude of middle stage students towards Reflective card Game.
4) To study the correlation between the Game Based Learning and Reflective Thinking Level of middle stage students in Biology.

1.14 Hypothesis

$H_0$1: There is no significant difference between the mean academic achievement scores of pre-test (BSAT-1) and post-test (BSAT-2) of the control group.

$H_0$2: There is no significant difference between the mean academic achievement scores of pre-test (BSAT-1) and post-test (BSAT-2) of the experimental group.

$H_0$3: There is no significant difference between the mean academic achievement scores of control and experimental group of middle stage students in post-test (BSAT-2).

H1: There is a significant difference between the mean academic achievement scores of control and experimental group of middle stage students in post-test (BSAT-2).

H2: Game Based Learning is more effective in improving student's reflective thinking level in comparison to traditional lecture method of teaching.

H3: There is a positive correlation between the Game Based Learning and Reflective Thinking Level of middle stage students in Biology.

1.15 Delimitations of the Study

- This study has been delimited to CBSE affiliated Govt. Senior Secondary School (Kendriya Vidyalaya, Sector-6) situated in Rourkela city of Sundargarh district, Odisha.
- This study has been delimited to middle stage Biology students of class VIII.
- Present study has been delimited to "Reaching the age of adolescence" topic covering sub-topics like 'Adolescence and Puberty', 'Changes at Puberty', 'Secondary sexual characters', 'Role of Sex hormones', 'Menstruation', 'Hormones and Endocrine glands', 'life cycle of frog' and 'Reproductive health'.