Incorporating Digital Play into Scientific Inquiry

by

Evelynn Jacob

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Submitted by: Evelynn Jacob

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Review Committee:

Research Supervisor	Dr. Brenda Jacobs
Second Reader	Dr. Diana Petrarca

The above review committee determined that the Project is acceptable in form and content and that a satisfactory knowledge of the field was covered by the work submitted. A copy of the Certificate of Approval is available from the School of Graduate and Postdoctoral Studies.

ABSTRACT

Play and inquiry have been recognised as effective facets of learning science (Vartiainen et al., 2020). Several researchers have highlighted the importance of incorporating digital play into K-12 students' science education (Edwards, 2013; Hartas, 2020; Johnston, 2021). As a result of the increase in online learning and technology use in classrooms, there is a significant need to develop effective interventions for digital play and science inquiry. The goal of this paper is to explore the role of digital play in science inquiry by giving an account of previous research initiatives on digital play and science education. The findings suggest that with the appropriate strategies used, digital play can improve students' experience during inquiry-based science activities.

Keywords: digital play; scientific inquiry, constructivist learning model

AUTHOR'S DECLARATION

I hereby declare that this project consists of original work of which I have authored. This is a true copy of the work, including any required final revisions, as accepted by my committee.

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STATEMENT OF CONTRIBUTIONS

I hereby certify that I am the sole author of this work and that no part of this work has been published or submitted for publication. I have used standard referencing practices to acknowledge ideas, research techniques, or other materials that belong to others. Furthermore, I hereby certify that I am the sole source of the creative works and/or inventive knowledge described in this document.

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1. Introduction

Play gained recognition several years ago as an essential component of learning, especially for young children (Moyles, 2005). The value of including play in science instruction for K–8 students has been emphasized by several researchers (Andrée & Lager-Nyqvist, 2013; Esnach & Fried, 2005; Fleer 2019; Hansson et al., 2021). This significant body of research has aimed to assess the characteristics of play from various theoretical vantage points (Fleer, 2019; Moyles, 2005). Some studies concentrate on student play, using Vygotsky (1967)'s idea of play as imagination in action (Vygotsky 1967; to create a framework for identifying and conceptualizing playful moments in classrooms (Andrée & Lager-Nyqvist, 2013).

Focusing on early childhood scientific education pedagogical approaches, it is necessary to maximize science learning opportunities (Hansson et. al, 2021). Fleer (2019) draws attention to the underutilised connection between play and imagination in science teaching. When science concepts are explored in fun ways, students are more likely to understand them (Bulunuz, 2013). Additionally, science inquiry gives teachers the chance to integrate their instruction with popular early childhood pedagogies like inquiry and play (Jacobs, 2022). Increased opportunities for science inquiry interventions in classrooms helps teachers gain the confidence and competence to teach science (Harlan & Rivkin, 2012).

Since inquiry-based learning can allow for more collaboration among peers, it enables teams of students to work together and learn (Jacobs, 2022). Students explore, discuss, and come up with innovative methods to approach a challenging subject while learning more as a team than they would individually, especially when they are provided with clearly defined responsibilities and expectations (Nicolopoulou et al., 2009). This form of peer learning gives students the ability to express their ideas and become active learners. Genuine interactions with peers frequently result in the most memorable experiences that students will remember from their science education (Fleer, 2019). Thus, the classroom becomes a setting for instruction. This can also result in teachers feeling more confident with regards to directly transferring the information to students themselves, therefore, gives them more confidence to teach science concepts (Harlan & Rivkin, 2012). In addition to helping students feel more confident with the subject matter they are working with, allowing more collaborative learning opportunities also alleviates the pressure teachers may feel in the classroom.

Despite the interest in increasing inquiry-based learning, there are well-established and ongoing concerns about the quality and quantity of science teaching (Kenny, 2010). Missed chances for children's science learning have been caused by the generalist nature of early childhood instruction and teachers' poor confidence in their background knowledge and competence to teach science (Knaggs & Sondergeld, 2015). These missed opportunities are concerning, given the increasing authentic learning context that science offers for fostering young children's inherent interest about the world around them.

With the pivot to online learning due to the global pandemic, children are using more technology in schools and educational settings (Ostermeier et al., 2021). This increase in technology use can be expected for future cohorts of students given that they will be more familiar with online learning pedagogy due to the impact of the COVID‑19 pandemic (Tahir et al., 2022). This includes an increase in students reading online articles, browsing websites, and even completing online assessments to show their learning. Similarly, play in school settings is also becoming more digitized in schools and early childhood education settings (Ostermeier et al., 2021). This practice of self-directed activity that involves using technology to support children's learning and development is described as digital play (Bird & Edwards, 2015). This includes activities like playing with electronic toys, using mobile devices like cell phones, iPads, and tablets, as well as playing video and computer games, visiting websites, and using search engines (Marsh, et al., 2016). Several studies focus on the area of digital play and highlight its importance in educational contexts (Bird & Edwards, 2015; Plowman et al., 2010). Despite the growing number of studies in the area of digital play, the role of digital play in scientific inquiry and its significance is still trying to be understood (Aubrey & Dahl, 2014).

This paper will aim to give an account of previous research initiatives on digital play and science education in order to explore the advantages of digital play during inquiry-based science activities. First, this paper focuses on the qualities of scientific inquiry and the importance of introducing children to the methods of inquiry. Second, the dynamic between digital play and scientific inquiry will be captured by examining the motive of how children and teachers negotiate with each other during the process of using digital tools in scientific play settings. Specifically, the paper seeks to exemplify where children need to learn how to use the software tools to successfully engage in inquiry processes in digital forms and to negotiate with one another socially and technically. This paper further explores how to support teachers and early childhood educators to effectively integrate science through digital play and inquiry pedagogies and thus, addresses some of the issues raised in the literature. The studies informing this paper are also outlined and the findings are used to inform a model for teacher practice.

1.1 Play Pedagogies and Theoretical Perspectives

Several philosophers, including Plato and Sartre, believed that when people play, they are at their most genuine, liberated, and creative state (Brown, 1959; Sartre, 1956; Schiller, 1884). Likewise, Vygotsky (1967) argued that the essence of play is the creation of imaginary situations. In fact, the construction of imaginative situations lies at the heart of play. Play develops from unsatisfied desires, therefore, children are naturally curious to find out how the world around them functions through testing and exploring (Eshach & Fried, 2005). Imaginary science situations can emerge from children's everyday wonderings about scientific phenomena and desire to investigate. In imaginary science situations, children can adopt the role of a scientist and then act as they believe scientists do (Andrée & Lager-Nyqvist, 2013).

Vygotsky (1967) stressed the importance of play for preschoolers and young children in elementary school to traditional dramatic or pretend play. According to Vygotsky (1967), play involves three elements: 1) children invent an imaginary scenario; 2) assume and act out roles; and 3) adhere to a set of rules established by these particular roles. As a result, when these three elements are involved, children can engage in self-regulated play (Andrée & Lager-Nyqvist, 2013). There is an intrinsic connection between the parts they play and the regulations they must go by in order to play those roles (Nicolopoulou et al., 2009). For example, children who are at the preschooler age, play is the first activity in which children are motivated by the desire to control their impulses rather than the urge for quick gratification, which is a common behavioural trait for preschoolers (Vygotsky, 1967).

Studies show that new developmental successes are manifested in play very early on (Manuilenko 1975; Elkonin 1978). These results confirmed Vygotsky (1967)'s hypothesis that play is the cause for developing and establishes the zone of proximal development (ZPD). This is referred to as the learner's capacity to successfully complete activities with the aid of a facilitator. By using scaffolded learning and support with cognitive task structuring, ZPDs can be created that are sensitive to the learner's existing abilities (Vygotsky, 1967). The ZPD is designed to be challenging; however, the activities are adjusted to the learner's level while providing the necessary scaffolding and support (Nicholas et al., 2021). Receiving scaffolded instruction from others can also teach children how to tackle challenging activities and manage their anxiety and frustration while doing so (Vygotsky, 1967). Therefore, the ZPD entails the transfer of power or responsibility for learning from the facilitator. The learner's interest in the task is also likely to be recruited through interaction inside the ZPD. The learner grows to value and appreciate the knowledge passed down from their teacher, as they reflect the respect for the learning which their teacher expresses (Vygotsky, 1967). By using play and scaffolded instruction, children are more likely to grow their ZPD and gain an appreciation for the subject related to the task they are presented with (Nicholas et al., 2021).

Piaget (1962) wrote extensively about the significance of play to intellectual development and provided theoretical support for the use of play as an intervention strategy. He explains that play is essential for cognitive development especially in the early years of a child's life (Piaget, 1962). Piaget (1962) also identified three stages of play's developmental process. The first is sensorimotor play, which typically entails reproducing a variety of previously learned behaviours ostensibly for amusement rather than to achieve a specific objective (Piaget, 1962). During the first two years of a child's existence, before symbolic and linguistic capacities emerge, this kind of play activity predominates. The ability for a child to utilise mental symbols to express experience improves when they reach symbolic play, the second developmental level of play (Singer, 1973). This is when pretend or make-believe play starts, therefore, resembling preoperational thought. In order to engage in symbolic play, a child must not only learn to assume other people's (animate or inanimate) roles but also remember past experiences in order to apply them to the present. Games with rules, which represent the third level of play, involves greater degrees of sociability and corresponding concrete operational abilities. These rule-based cooperative and competitive activities flourish during a child's years in school (Piaget, 1962).

According to Piaget (1962), the stages of play and imitation behaviours contribute to the development of intellect. Imitation is the capacity to duplicate either observable or unobservable behaviour, or both. Since imitation includes not only seeing one's own and other people's complicated behaviour, but also representing these observations through either overt or covert mediational activity, it is associated with mental capacity. Piaget (1962) believed that imitative abilities significantly increase from birth to about age two. By helping to differentiate, coordinate, and generalise already-present actions as well as by enabling the child to add new behaviours, imitation skills support mental development (Garwood, 1982). Young children learn certain skills and how to coordinate reactions for greater problem-solving abilities through play. Therefore, play is crucial for the growth of intelligence (Piaget, 1967). For these reasons, preschoolers are substantially more functional and constructive than they are when playing games or being dramatic (Rubin & Maioni, 1975).

According to Csikszentmihalyi (1975), different types of play have a common experiential state, which is also present under certain circumstances in other activities that aren't typically thought of as play. Csikszentmihalyi (1975) calls this feeling flow, which refers to the entire experience we have when we behave wholly engaged. It is the sort of emotion that makes one go back with nostalgia and reflect on the experience as being fun and enjoyable (Csikszentmihalyi & Bennett, 1971). Flow is the condition in which things happen one after the other in accordance with an inherent logic that doesn't seem to require our conscious involvement (Csikszentmihalyi, 1975). There is little separation between self and environment, stimulus and response, or past, present, and future, and individuals experience it as a continuous flow from one moment to the next in which they feel in control of their activities (Csikszentmihalyi, 1975). Flow doesn't seem to happen unless a person is actively participating in a specific type of environment-related interaction. The engagement may be largely physical, emotional, or intellectual, but in each instance the individual is able to act on a specific region in an individual’s surroundings using particular skills (Csikszentmihalyi & Bennett, 1971). Therefore, in order to grasp the flow experience, one must also take into account the flow activities.

Csikszentmihalyi (1975) further explains that play is the most frequent type of flow experience, and games are the most popular play activities. However, in reality, most people require some sort of provocation to engage in flow activities, at least initially, before they develop an awareness of intrinsic pleasures (Csikszentmihalyi, 1975). Children can act out conflictual circumstances in play, especially dramatic play, so that they come out on top and so that their sense of mastery or competence is not completely weakened or affected by conflictual experiences (Garwood, 1982). Therefore, one is largely liberated from the constraint of having too many demands while playing. Play is not a simple response to environmental pressures, but a relatively spontaneous act of the organism (Csikszentmihalyi & Bennett, 1971). Accordingly, play and cognitive development are linked by the positive correlation between dramatic play and categorization and spatial skills.

Different types of play experience aid in children's learning and development, and Pellegrini (2009) reveals how social pretend play is an example of an effective means for children’s development. While a variety of circumstances affect how children play, the incentive that many preschoolers have for spontaneously engaging in social pretend play lends credence to the claim that it is the primary activity of the preschool age (Pellegrini, 2009). Understanding how social pretend play helps psychological, social, and motivational components of development in an integrated manner is made easier by using the framework provided by leading activity theory (Whitebread & O'Sullivan, 2012). The non-literal setting continues to require children to engage in object and ideational processes of transformation, which supports symbolic thinking. As youngsters use roles, relationships, and accompanying emotional experiences to create group pretend episodes, socio-emotional aspects of development are also fostered. Additionally, a wider variety of metacognitive and self-regulatory behaviours must be practised in order to maintain the collectively planned and maintained reality (Whitebread & O'Sullivan, 2012).

The most prevalent assumption regarding why play aids learning is probably that it is motivating (Whitebread, 2018). According to Whitebread (2018) play is joyful, entertaining, and inherently motivated as a result. Play is generally accompanied with positive effects on the brain, according to a recent overview of neuroscientific studies on play's characteristics that have emerged from the corpus of research (Liu, 2020). This correlates to the release of the neurotransmitter dopamine on a neurological level, which improves the functionality and performance of the parts of the brain that control attention, working memory, mental flexibility, and stress levels (Goldberg, 2009). Dopamine release appears to promote the mechanisms underlying both creativity and curiosity (Gruber, Gelman, & Ranganath, 2014). Therefore, play is meaningful to the child, encourages active involvement and repetitive intentional behaviour, and is frequently socially interactive (Whitebread, 2018).

Whitebread (2018) argues that all forms of play, whether they involve physical activity, artistic expression (such as painting or music production), or rule-based games, share the same motivational characteristics. But studies looking at how play helps kids develop their symbolic or representational skills have tended to emphasize pretense or pretend play (Leslie, 1987; Pellegrini, 2009; Weisberg, 2015). Children start to use language and pretend about the time they turn one. Being able to utilise one object to stand in for another is necessary for both of these actions. As a result, they are both symbolic and representational systems, and it appears likely that their growth will remain tightly intertwined (Weisberg, 2015).

A systematic review of the evidence relating to pretense play, by Leslie (1987), broadly supported the position concluding that the most plausible developmental outcome of pretend play is the development of language and narrative abilities, and that the influence appears to be bi-directional. Christie and Roskos (2006) conducted a review of the research to support this claim, finding that playful language learning by parents, as opposed to formal instruction, provides the strongest support for the early development of phonological and literacy skills. While the development of language skills is obviously significant in and of itself, it is also significant in that it allows for the development of internal verbal representations supporting abstract thought as well as the capacity for working memory, a skill that underpins nearly every aspect of mental activity (Christie & Roskos, 2006). Thibodeau et al., (2016) found evidence in their intervention study on the effects of pretence play, finding that children who regularly engaged in imaginative fantastical play significantly outperformed children in control groups in terms of improving their working memory scores.

Therefore, a hypothetical scenario might inspire children to communicate in ways that help them make sense of their surrounding environment and solve problems (Caiman &

Lundegård, 2018). That is, play and imagination can facilitate the process of translating ordinary conceptions into scientific concepts (Fleer, 2019). As a result, material resources and activities that facilitate the transfer to the hypothetical scenario are crucial in scientific teaching. Stories and narratives can help children apply scientific concepts in the real world and make connections between their scientific learning and reality (Ferholt et al., 2018; Fleer, 2019). This can be seen in playworlds which involve the teacher in the play of the children and emphasizes a problem scenario as a component of creating a play narrative (Hakkarainen et al., 2013). Playworlds assigns an adult a pedagogical position that actively encourages creativity, which has been found to foster children's imaginative play (Lindqvist, 1995). A shift away from reality is noted when a child confronts an item with new meanings and modifies its function (Vygotsky, 2004). However, in a child's role play, this dual role of creative circumstances is frequently brought up and presents opportunities for children to understand real world contexts (Ferholt et al., 2019).

Vygotsky (1967) illustrates that children must play consciously in order to maintain play, and avoid behaviour that does not fit the designated role. They must first voluntarily abide by the rules that specify which behaviours are appropriate for each particular function and which ones are not (Bodrova et. al, 2013). Such play planning paves the way for reflective thinking, which is a component of self-regulation (Vygotsky, 1967). Recognizing a child's capacity to take in and understand information, is essential to comprehending the complicated nature of self-regulation (Goldberg, 2009). Children’s ability to maintain calm concentration and alertness affects how well they assimilate, organise, and integrate the variety of information that comes to them through their senses (Shanker, 2010). Therefore, integrating play into children’s learning environment can significantly help them develop necessary life skills.

In learning environments, imaginative scenarios may either move a child toward reality or away from it (Vygotsky, 2004). For example, when I worked in a summer preschool program, I observed the children role-playing different characters. Children who pretended to be thieves and police officers, were exploring the laws of society and so moved towards understanding reality. Similarly, children role-playing as doctors and patients may have been exploring the physiology of the human body, again reflecting a shift towards reality. Therefore, when imagination and practical problem-solving combine, an imaginary circumstance can enhance children's developing comprehension of scientific concepts and procedures (Hakkarainen, 2008).

Piaget (1962), Vygotsky (1967), Whitebread (2018) and Csikszentmihalyi (1975) illustrate the importance play has in a child’s development since it caters to a child’s natural curiosity about the world around them. Play encourages the development of self-regulation by requiring participants to be aware of and restrict themselves when acting out roles (Goldberg, 2009). Children use their imagination to endow items with new meanings, which is one of the features of play (Vygotsky, 1967). For example, language plays a significant function in this context as a social and cultural instrument for sharing and co-creating scientific concepts and procedures (Vartiainen et al, 2020). Similarly, children's use of scientific concepts, explaining or planning scientific procedures, and presenting and assessing outcomes are all examples of science speech and communication. Scientific notions, on the other hand, do not emerge organically from common concepts through imagination and play, but rather require social and cultural scaffolding from a facilitator who can introduce and explain new scientific vocabulary (Vygotsky, 1987a). As Vygotsky (1987) states, science is impossible without imagination.

1.1 Play Pedagogies and Learning Models

Play pedagogies are common in early childhood educational settings, and they appear to provide a variety of chances for students to engage in scientific inquiry (Vartiainen, 2020). The learning that takes place during play is described by contemporary theorists as being culturally determined and impacted by the experiences, identities, and skills of the participating children (Wood, 2013). Furthermore, the social and cultural environment in which this learning takes place must be considered (Vartiainen, 2020). Through the concurrent recognition of the significance of the features of experience, identity, and ability in the social and cultural learning environment, this theorization of learning through play offers a bridge to science instruction (Wood, 2013). This bridge strengthens the connection between the early childhood teachers' current practices and knowledge of pedagogical material to the less familiar domain of scientific inquiry. Learning through play provides a meaningful environment for scientific investigation, which is also influenced by sociocultural theory in current research (Tytler, 2002).

The method of learning through which students understand their surrounding environment using their life experiences and sensory interactions is reflected in the constructivist learning model (Bryceson, 2007). This theory of learning is based on Piaget's work and describes how people construct knowledge as new information is perceived and compared to prior understanding. It also refers to the idea that knowledge develops through constantly changing internal processes as people create meaning from their interactions with their environment (Bodrova et al., 2013). According to Bencze (2000), constructivism is a learning model that is an opportunity for learners to gain knowledge by merging novel ideas with prior cognitive knowledge which they already have. This can help make the information meaningful to learners, as well as allow the learning outcomes to be retained in students' memory (Maor, 1991).

The constructivist learning model can, therefore, be considered an effective method of learning which offers many opportunities for playful exploration. Educators who have the responsibility of teaching students science concepts must cater to their students' unique learning preferences and expose them to conventional methods of science that they may not have experienced before. Thus, science educators can work towards preparing students for different scientific topics that have underlying socio-cultural ideologies with which students can make connections. This approach to science education reflects the constructivist learning model since students are not forced to follow a strategic path of learning which was preplanned, but can be mediators of their own learning while choosing their own paths (O' Loughlin, 1992). In fact, this learning model requires students to be active participants in their learning. Since students have pre-existing ideas based on their personal and social experiences about different science topics, teachers can manifest those ideas and use them in a way that caters the lesson to their students and gauge their interest. Therefore, constructivism can be described as the connection between students' life experiences that reflect their natural phenomena (Schulte, 1996).

Constructivist models of learning respect students as unique individuals with their sociocultural backgrounds (O' Loughlin, 1992). They allow for children to actively participate in inquiry, problem-based learning and experiential learning (Maor, 1991). These models of learning can be regarded as brain-compatible approaches because they foster trust and create secure, non-threatening, yet challenging learning environments (Schulte, 1996). They provide a rich learning environment, meaningful and realistic experiences, in which learners are given a variety of options for activities. Additionally, children are provided the necessary time and opportunities to become active learners to process and reflect on what they are learning and experiencing (Shymansky et al., 2000).

Emergent curriculum, which incorporates the constructivist learning paradigm and was influenced by the Reggio Emilia approach, has a long history in North America (Wien, 2008). Loris Malaguzzi, who helped to develop the Reggio Emilia approach, argued that what children learn does not always flow from and remember what has been taught (Lindsay, 2015). Instead, as a result of their actions, activities, and resources, youngsters learn mostly at their own initiative (Biermeier, 2015). As the creator and leader of the renowned Reggio Emilia municipal preschools, Malaguzzi was a proponent of a blend of theory and practice that encourages teachers to view students as capable and competent learners in the context of group activity (Fraser & Grestwicki, 2002). Furthermore many early childhood education programs were developed in preschools that are tailored to the cultural setting, language, history, geography, and political and economic life of the region and its inhabitants (Biermeier, 2015).

According to Lindsay (2015), the Reggio Emilia project's key tenets of practice centre on social reform through access and equity, the idea of children's democratic rights as citizens, strengthening community partnerships and democratic participation, images of children as capable competent co-constructors of knowledge, the role of educators as researchers and co-learners, and the use of pedagogical documentation in support of assessment advocacy, reflection and re-evaluation (Edwards et al., 2012). By using the environment as the third teacher, the Reggio Emilia method achieves high quality learning (Lindsay, 2015). The physical environment is very significant in Reggio-inspired schools. For example, having a focus on aesthetics and visual art around the classroom that is representative of the children's learning can help students feel excited to learn and participate in class (Gandini, 2002). Children are capable of empowering themselves, and the classroom should reflect this by encouraging children to express their ideas in an open way (Fraser & Grestwicki, 2002).

The Reggio Emilia approach, which holds that the teacher and the environment both have a role in how knowledge is created (Gandini, 2002) is based on the socio-constructivist theory which was developed by Lev Vygotsky. In his view, learning entailed more than just the assimilation and accommodation of new knowledge by learners; rather, it was the process by which learners were integrated into a knowledge community (Vygotsky, 1978). Vygotsky (1978) explained that the learner achieves their actual developmental stage when they can solve issues on their own, which is considered to be their current developmental stage. As mentioned earlier, the degree of potential growth, also known as the zone of proximal development (ZPD) is the level of development that a learner is capable of achieving while working with peers or with the assistance of teachers (Vygotsky, 1967). The level of potential development is the level at which learning occurs; the learner is capable of understanding material and solving issues at this level that they are unable to do at their current level of development (Nicholas et al., 2021).

Vygotsky (1978) further argued that all cognitive functions originate in social interactions and must therefore be explained as byproducts of social interactions. Social constructivism emphasizes the collaborative aspect of learning, according to Vygotsky (1978). Therefore, the idea that students and teachers are capable resources and strong protagonists of their own experiences is a crucial component of its ideology (Moss, 2016). This suggests that standardised, formulaic and teacher-proof programs fall short of maximizing both teachers' and students' creative potential. Emergent curriculum places a strong emphasis on students' and teachers' sincere interests since it prioritises motivation (Wien, 2008).

Participation of the educator and the student is very important for education and learning to take place. Interest and motivation can be ensured, if they let children and teachers explore their own inquiries, their theories about how things operate, and their own methods for putting things into action and understanding the world (Wien, 2008). When students are motivated to learn and interested in the topic, it propels learning and carries the learner through the program (Fraser & Grestwicki, 2002). Learning consequently becomes natural and inspired because the motivation's energy carries the will (Lindsay, 2015). Children recall the things that make them feel the most strongly (Gandini, 2002). Strong emotional feelings concerning learning competitions increase the likelihood that they will be remembered (Lindsay, 2015). Such vivid and positive experiences help to shape children's identities as learners and teachers' identities as teachers because people tend to forget what is not necessary to function (Wien, 2008). This method's creative process always starts with an inquiry or a question about an unidentified issue, which prompts participants to look for, develop, or make a workable solution . The context of a problem determines where creativity originates from, and originality results from the variety of local circumstances and the individuality of each child (Wien, 2008).

Overall, the research on sociocultural theory shows that play provides a useful atmosphere for scientific inquiry (Tytler, 2002). Incorporating play in science inquiry can strengthen early childhood teachers' pedagogical knowledge and expertise (Wien, 2008). Furthermore, the benefits of play can be brought out effectively in a collaborative learning environment through the use of emergent curriculum, therefore, incorporating a constructivist learning paradigm (Fraser & Grestwicki, 2002). As a result, students can receive science education in a way that respects them as unique individuals with their own interests, therefore, allowing them to associate the subject with positive feelings.

1.2 Play and Science Inquiry

As discussed, teaching students science concepts through a less traditional approach is being accepted as a beneficial facet of learning, particularly in science education (Tytler, 2002).

Approaching science education through hands-on and experiential practices allows for students to use their imagination and learn through play. Students learning science through inquiry are actively participating in their learning and making connections to the world around them and experiences with phenomena (Tytler, 2002). This is through frequent questioning and exploration, with the addition of teacher interventions to ensure students are directing their learning towards the lesson's outcome (Fraser & Grestwicki, 2002).

By incorporating hands-on and experiential practices in science education, students might engage with their senses and natural phenomena, students are able to come to their own conclusions, therefore, making the overall learning experience memorable (Lindsay, 2015). These characteristics of science teaching produce a learning environment that is more reflective of the constructivist learning model. As a result, the learning process will resonate with students longer than if they were to have been exposed to science topics through a more traditional teaching style (Fraser & Grestwicki, 2002). The key difference is that through the constructivist learning model students come in with their pre-existing ideas and leave with confirmed or adapted views about that topic, as opposed to being told what is right. Again, this reflects the traditional teaching method teachers may use when teaching scientific concepts (Schulte, 1996).

Students are given the opportunity to communicate their ideas while the teacher is listening to them and motivating active participation (Tytler, 2002). That being said, effective execution of scientific inquiry and instruction entails students having experiences of exploring and discerning non-scientific concepts alongside reassuring and supportive teacher facilitation (Gandini, 2002). Furthermore, educators have an important role in creating a variety of interesting activities and assessment tools that cater to the different science topics in the curriculum (Tytler, 2002). Although meeting curriculum expectations and guidelines may be perceived as an obstacle for teachers when planning creative and engaging activities for students, teachers are pushed to find resources and create tasks that align with the overall learning goals (Fraser & Grestwicki, 2002). These tasks must be engaging to gauge student interest and also challenge them in order to guide them in their questioning process and ongoing investigations (Maslow, 1968).

Another key aspect of executing effective science inquiry in the classroom is to promote a collaborative learning environment (Fraser & Grestwicki, 2002). This does not have to be the case with every activity, however, tasks that require teamwork and collaboration allow for students to engage in scientific talk with their peers and build off each other's ideas, therefore, drawing richer and more well thought out conclusions (Tytler, 2002). This type of learning environment reflects the social constructivist theory, allowing students to engage in the collaborative aspect of learning. Gallas (1992) describes science talks as how young children communicate about science, and how they construct conceptions about complex scientific issues through the use of metaphors and analogies. Young children ask challenging questions about their world and attempt to find answers through science discourse. Science instruction, like teaching in general, demands that teachers play a number of roles to ensure that students are staying on task, providing clarification and a clear framework when necessary, and help students to work towards a goal (Tytler, 2002). However, these kinds of descriptions also emphasize the significance of intention in negotiating interpretations of texts (Gallas, 1992).

Children's linguistic interactions can have a range of consequences on students, both positive and negative on students, some of which teachers are unable to control on their own (Gallas et al., 1996). Explicit instruction that involves appropriate science vocabulary during particular classroom literacy activities is undoubtedly necessary (Gandini, 2002). To assist students in using appropriate science vocabulary, teachers can guide the class through the practice of explicit talk protocols (Gallas et al., 1996). According to Gallas et al., (1996) teachers must conduct a thorough, contextualised analysis of the speech events occurring in their classes if they are to enable students to bring their oral language traditions into the centre of classroom life and then identify strategies to strengthen and expand those traditions. Or, to put it another way, planning and teaching oral language experiences must also take into account the talk that emerges from such experiences (Gallas et al., 1996). As students attempt to carve out a space for themselves in the social environment, these oral dialogues that include science vocabulary show the lengths that discourse and texts can go (Fraser & Grestwicki, 2002).

In addition to communicating their thoughts with each other, with regards to comprehending scientific concepts, children are concrete thinkers who also require hands-on experience. This includes holding, breaking, loading, and moving various types of objects, as well as pouring and mixing various types of liquids (Banchi & Bell, 2008). For example, children can understand the concept of floating and sinking through hands-on activities that involve placing different objects in the water in a kindergarten classroom (NGSS, 2013). Children show signs of great excitement when participating in experiments that allow them to predict whether an object will float or sink (Pramling-Samuelsson et al., 2008). In this fun and experimental environment, the teacher's role was to help children explain their predictions and assist them in turning them into testable questions and assist them while thinking, reflecting, and verbalising. The teacher intervened to inquire what would happen to the object when released into the water, regardless of what the child chooses. Students would respond and act, and have the opportunity to attempt it again and again. In this situation, the teacher's goal was not to lead the child to the correct answer, but allow the child to come to a decision on their own through their inquiry.

Allowing children to interact with materials is the first step in learning science. Children, on the other hand, become aware of science ideas as a result of these hands-on activities (Krnel et al., 1998). Teachers must direct children's attention to science topics by utilising natural science language in context to enhance concept awareness (Clark, 2001). Children must act on materials through experiencing them in order to comprehend the scientific concepts (Krnel et al., 1998). If learning is made relevant and presented in a tangible way, children may acquire rather abstract concepts (Fleer, 2019).

Children develop a variety of abilities in a fun learning environment which allows for participating, watching, communicating, predicting, planning, researching, categorising, experimenting, altering factors, and concluding (Banchi & Bell, 2008). An effective science education program for young children should set up explorations and experiences from which children can build on their curiosity, allow for repetition and variation, help children develop meaning and develop scientific understanding from their experiences based on the important qualities of both play and learning (Pramling-Samuelsson et al., 2008). This learning experience becomes even more valuable to students when they are provided with the opportunities to collaborate with one another and communicate their ideas out loud (Jacobs, 2022). Including these factors in a science classroom would reflect a learning environment that promotes and leads into opportunities for scientific inquiry.

1.3 Understanding the Models of Inquiry

Authentic science practices must be taken into account while designing engaging and authentic science lessons for students. According to the Next Generation Science Standards, one of the three elements necessary for ensuring student achievement in scientific education is science practises (NGSS, 2013). The ideas and expertise that scientists employ in their discipline-specific research are referred to as "science practises." Although it is acknowledged that inquiry is crucial for the growth of scientific thinking abilities, many classroom activities in K–12 and college settings are restricted to straightforward, unauthentic inquiry exercises. Activities that mimic the procedures used by working scientists are referred to as authentic science inquiry (Peffer et al., 2015). The sorts of inquiry that students encounter in K–12 and college settings can help them develop a scientific understanding that is more in line with the methods used in practice.

According to Banchi and Bell (2008) students can advance through a continuum of four levels of inquiry as they develop more sophisticated scientific reasoning. The four levels–confirmation, structured, guided, open–differ based on the amount of information provided to students and guidance offered from the teacher (Banchi & Bell, 2008).

Students are given the question and the method (process) for the first level, or confirmation inquiry, and the outcomes are known beforehand (Banchi & Bell, 2008). Confirmation inquiry is helpful when a teacher wants to have students practise a particular inquiry skill, such as gathering and recording data, or to introduce them to the experience of doing inquiries. To demonstrate this concept, students might make paper helicopters with varying length wings. They conduct the experiment as instructed, record their data, and examine their findings (Banchi & Bell, 2008).

The question and process are still provided by the teacher at the next level of structured inquiry, but students create an explanation that is supported by the data they have gathered.

Although confirmation and structured inquiry are regarded as lower-level questions, primary science programmes frequently use them. These kinds of questions are crucial because they give students the chance to gradually build the skills necessary to undertake more in-depth research (Banchi & Bell, 2008).

At the third level, guided inquiry, the teacher just presents the research topic to the students; the approach (method) to test the question and the ensuing explanations is created by the students themselves (Banchi & Bell, 2008). This type of inquiry is more involved than structured inquiry, therefore it works best when students have had plenty of opportunities to study and practise various methods for designing experiments and keeping track of results (Banchi & Bell, 2008).

Students have the most possibilities to act like scientists at the fourth and highest stage of inquiry, open inquiry, when they develop questions, plan and conduct research, and present their findings. The most scientific thinking and cognitive strain are placed on students at this level (Banchi & Bell, 2008). Students at the fourth and fifth grade levels will be able to successfully conduct open inquiries since they have had enough of experience with the first three levels of inquiry. When students have proven they can properly plan and perform investigations when given the question, it is only appropriate to have them do open inquiries. This includes having the ability to gather evidence, record it, analyse it, and draw conclusions from it (Banchi & Bell, 2008).

Students can experience multiple levels of inquiry during a single lesson or unit with related scientific concepts (Banchi & Bell, 2008). Play pedagogies that emphasize vocabulary, communication, and social development allow for play and science inquiry to work together

(Peffer et al., 2015). Play has the potential to improve teachers' capacity for scientific inquiry, therefore, acknowledging this bridging is crucial (Vygotsky, 1967). These play pedagogies are comparable to the science inquiry abilities of questioning, predicting, researching, analysing, explaining, and communicating (Banchi & Bell, 2008). Additionally, certain basic literacy skills that are linked to science inquiry arise through play, such as bargaining, information sharing, discussing and sharing issues and solutions, reasoning, explaining, recommending, and questioning (Peffer et al., 2015). This highlights even more how play pedagogies offer opportunities for scientific investigation. Campbell (2012) points out how these and other aspects of play-based learning, such creativity, abstract thought, and exploration, are compatible with the abilities and practises of scientific inquiry. In early childhood settings, where children's literature serves as a source of contextual themes for science learning and play serves as the pedagogy for its implementation, these synergies might offer a method to think about scientific inquiry (Peffer et al., 2015).

In order to integrate play and science effectively, it is necessary to provide a variety of play experiences for children so that they can become aware of science topics. It is beneficial to include various activities that can reinforce science concepts and reflect the different levels of inquiry (Campbell, 2012). This includes letting students go outdoors and examine the insects on the ground, play in the sand to understand states of matter, or use music and dance to represent different stages of metamorphosis (NGSS, 2013). Children indeed require repetition, however, it is important to think of different ways to engage children and present them with new play opportunities in the classroom (Peffer et al., 2015). This corresponds to studies which show that students who had more variations in the guided inquiry and play setting were more attentive, and their reasoning abilities in describing scientific facts increased more than students who had less variants (Fraser & Grestwicki, 2002). Furthermore, studies reveal that a high level of fun and attention aids in the acquisition of scientific concepts (Pramling-Samuelsson et al., 2008).

2. Understanding Digital Play

2.1 What is digital play?

Play-based activities are supported by the imaginative aspect of play and the fulfilment of interacting with peers. This includes both face-to-face and digital play. Due to the COVID-19 pandemic’s effects and the resulting changes in how society functions, children's use of digital technology has grown (Tahir et al., 2022). Touchscreen technology has become increasingly popular as a means to entertain and engage children (Johnston, 2021). As the world gets used to living with the pandemic, it is anticipated that some of these changes may persist into a new normal (Ostermeier et al., 2021). Due to the growing accessibility of touchscreen devices with Internet capabilities, young children's screen time usage had increased even before COVID-19 took effect. The ease with which young children can utilise touchscreen devices has increased engagement and led to a larger variety of digital play (Lowrie & Larkin, 2020). Children frequently interact with touchscreen gadgets and apps as babies, and children are using the Internet by the time they are four years old (Danby et al., 2018). According to other studies, the vast majority of children between the ages of one and sixteen now have access to a tablet (91%) or smartphone (86%) and frequently engage with digital content on websites, including YouTube (Burroughs, 2017).

Digital play can be defined as a self-directed, energizing activity that entails utilizing digital tools to aid in children's learning and growth (Bird & Edwards, 2015). This encompasses pursuits including electronic toys, mobile technology, cell phones, iPads, and tablets, as well as video and computer games, websites, and search engines. In existing studies that provide the background for the present research, a number of research outcomes are evident (Hartas, 2020). First, what is known about children’s engagement with technologies is based mostly on parents’ self-reports from family contexts, with less known about the digital play of preschool children in free play settings (Johnston, 2021). Not much attention has been paid to children's group interactions in preschool settings where teachers have an educational agenda (Burroughs, 2017). These contexts are likely to be different, and as such, more needs to be known about how the introduction of digital devices and tools designed for educational purposes create new conditions for children's play, as well as how children appropriate the teacher's agenda for learning (Bird & Edwards, 2015).

Overall, digital activity does not seem to interfere with children's interaction with the real world, interpersonal interactions, or learning (Hartas, 2020). Given that their limits are muddled and are better understood when placed on a continuum of social experience (Johnston, 2021), this illustrates how difficult it is to distinguish between digital and face-to-face contact during peer interactions.

In response to this issue, the idea of digital play in schools is developing (Lowrie & Larkin, 2020). Digital play is variably thought of as the variety of activities children engage in using technology in a play-based approach or the introduction of a new modern kind of play that incorporates children in digitally mediated situations (Bird & Edwards, 2015; Lowrie & Larkin, 2020). Work on the idea of digital play has been important for early childhood education because it aids teachers in understanding how young children utilize technology and, consequently, play-based learning (Bird & Edwards, 2015). This means that, in a similar way to how descriptions of children's pretend or exploratory play can be used to inform the provision of experiences like role or construction play, descriptions of children's digital play are useful for educators because they can be used to inform the use of technologies in early childhood settings (Hartas, 2020).

The idea of wellbeing is being recognised as a crucial indicator of good growth (Hartas, 2020). There is discussion of what wellbeing looks like in the context of young children's digital play, both in terms of the study of digital play specifically, as well as more generally in terms of how digital play affects a child's sense of overall well being (Johnston, 2021). Digital wellbeing offers a way to think about how screen time and digital technology can be integrated into children's lives in a way that has a positive impact on learning, development, and long-term outcomes given current concerns about the addictive nature of technology and the impact of increased screen time on children's development (Hartas, 2020). The flow theory, outlined by Csikszentmihalyi (1975), enables participation in digital play to be taken into account alongside other types of play. This is especially valuable because it allows for digital wellbeing to be achieved despite the intense absorption of digital technology that might be perceived as problematic (Hartas, 2020).

One drawback of the existing research on digital play is that it does not clearly describe how children pick up technology skills through play (Bird & Edwards, 2015). It is challenging for educators to examine and evaluate young children's technological learning without a foundation in the understanding of how children learn to utilise technologies through play (Aubrey & Dahl, 2014). Edwards & Bird (2017) developed the Digital Play Framework as an assessment tool to assist educators in comprehending how children learn to use technologies through play in response to this issue.

The Digital Play Framework claims that before transitioning to symbolic play, children must first learn technologies called epistemic or exploratory play (Edwards & Bird, 2017). According to Vygotsky (1997), utilising a tool enables people to complete a task. Play frequently serves as the focus of children's activity in early childhood educational settings (Wood, 2013).

Hutt et al., (1989) explains that children should engage in exploratory play with artifacts until they have a firm grasp of what each one performs. In fact, Hutt et al., (1989) goes on to differentiate between two types of play, ludic and epistemic play. In epistemic play, children are seen participating in exploratory play that is focused on figuring out "what does this thing do?" (Hutt et al., 1989). On the other hand, during their play children can also ask "what can I do with the object?" This is perceived as ludic play, children are shown using the item to engage in imaginative and creative play (Hutt et al., 1989). When children use an object in novel ways to achieve their own objectives, their activity transforms into ludic, or symbolic play, rather than seeking to comprehend how it works (Bird & Edwards, 2015).

In order to create the Digital Play Framework, Bird and Edwards (2014) have suggested that children learn to use technologies through play by transitioning from epistemic to ludic play. This is because Vygotsky (1967) argued that mastery of a tool transforms the object of action. Until they have mastered the functions of the technology-as-tool, they use it as an instrument while the goal of their activity is epistemic play. At that point, they switch to utilising it as a tool for realising ludic play. Therefore, as potential markers for children learning to utilise technologies through play, the Digital Play Framework includes behaviours linked to the description provided by Hutt et al., (1989) of epistemic and ludic activity, such as exploration, problem solving, and skill acquisition.

Descriptions of passive versus active screen time as a gauge of educational appropriateness are no longer necessary given more recent studies on digital play (Lowrie & Larkin, 2020). Instead, the use of digital technologies in early childhood settings should take into account the play-based learning that should take place "before," "after," and "during" contact with the device. As a result, when children are playing, they might conduct imaginative experiments in which they see some insects outside, use the tablet's miniature microscope to examine some of the insects' details more precisely, and then either draw the insects or act like they are the insects (Ross, 2000). According to this theory, children naturally engage in play through the use of digital technology (Lowrie & Larkin, 2020). The fact that digital technology must promote children's learning through play when they choose to utilise it rather than limiting it is what matters most in this concept.

Digital citizenship, a concept more commonly associated with young children's online experiences, overlaps with digital wellbeing as a result (Mattson, 2017). Digital citizenship is the requirement for adults and children to be responsible digital citizens through an understanding of the use, abuse, and misuse of technology as well as the norms of appropriate, responsible, and ethical behaviours related to online rights, roles, identity, safety, security (Lauricella et al., 2020). This definition emphasizes the need to assist young children with more than just technology handling abilities (Mattson, 2017).

Digital play and interaction can help children develop self-regulation with adult guidance and support, but again, this must be done with purpose, consideration, and knowledge (Plowman et al., 2010). Developing the abilities and agency of the children is essential to this process. A solution that solely focuses on banning or restricting screen time, for instance, does not allow kids to learn the skills they need to self-manage their time and involvement (Lowrie & Larkin, 2020). Similar to the last example, while adult-controlled filters, limitations, or even co-viewing with a child can enhance safety, they do not give children the ability to develop self-regulation abilities (Lauricella et al., 2020). Instead, developing young children's capacities to assess and analyze content as well as self-regulate their involvement and behaviour can enable good digital citizenship. The emphasis on play-based learning and on preserving and enhancing children's agency are essential to developing these skills.

2.2 How can digital play be incorporated into scientific inquiry?

The potential of digital play for developing educational experiences that motivate students to explore the subject material with the same zeal that they learn rules and strategies in well-designed commercial digital games has long been recognised by educational researchers and producers (Martin et al., 2019). There is a need to learn more about children's ability to exercise agency in digital domains (Martin et al., 2019). The most likely group to be forgotten while thinking about this topic is young children (Chayko, 2018). High expectations for young children's skills while remaining mindful of overstating or assuming knowledge are essential components of this strategy. Children's engagement or interest in technology does not always reflect a sophisticated or in-depth understanding (Johnston, 2021). Therefore, it's critical to make sure that teachers and family members are aware of both the advantages of digital play (Lowrie & Larkin, 2020).

Studies confirm the necessity to scaffold and support children in digital settings in order to foster their independence, agency, and empowerment during scientific inquiry rather than monitoring and safeguarding them. As Banchi and Bell (2008) highlight, primary science programmes frequently use the confirmation and structured inquiry models which recognizes the importance of teacher facilitation and scaffolded instruction. This inquiry model can be applied even when children engage in inquiry through digital play where teachers can have students practise a particular skill. This kind of guidance and prompting is crucial because it gives students the chance to gradually build the skills necessary to undertake more in-depth research (Johnston, 2021). This is crucial so that children are engaged in scientific inquiry through digital play that can pique their interest. It is through this approach that teachers will be successful in offering a learning experience that reflects an emergent curriculum since it relies on the students' and teachers' sincere interests and prioritises motivation (Wien, 2008).

To strike a balance between having high expectations and not underestimating capacity, the teacher can set aside time to discuss the children's use of digital technology (Johnston, 2021). Open communication with children, asking them to share what ideas of safe technology use can prepare them with the tools they need to understand the material better and understand their capabilities and interests (Wien, 2008). Furthermore, allowing students to discuss their thoughts beforehand reflects the collaborative learning environment required for inquiry which invites student voice (Jacobs, 2022).

Therefore, teachers must decide how to best lead and scaffold the development of skills that will support wellness, such as balancing screen time with other activities, evaluating content, and exercising self-control and self-regulation (Hartas, 2020). Shanker (2010) explains that self-regulation involves lowering the frequency and strength of strong impulses by controlling stress-load and recovery, whereas self-control involves resisting strong urges. Young children's self-regulation in digital environments must be taken into account together with a thorough grasp of these developmental paths, both in terms of expectations for children's conduct and in terms of the direction and assistance needed (Johnston, 2021). When teachers are knowledgeable about the technology children engage through digital play, it may serve as an additional asset to successfully assess and mentor the learning.

2.21 Using analogies to connect scientific inquiry and digital play

Teachers can draw on the implicit learning that occurs when students interact with digital play, such as game mechanics or possible challenges to look out for, through open conversations to help students explicitly understand the scientific ideas the games are meant to depict (Culp et al., 2015). In order for students to connect what they learned from the digital play they engaged in to real-world concepts and content, teachers must help them reflect on the gameplay methods used (van der Meij et al., 2013). When implementing digital play in science inquiry, the teacher acts as a co-learner who works collaboratively with students to help them understand the information at hand through scaffolded instruction. This allows for the abilities and techniques to be transferred to a target disciplinary area (Culp et al., 2015). Again, inquiry entails students to share their thoughts to reinforce that their voice is valuable. However, this form of digital play may seem more teacher directed which can be considered as a limitation of incorporating digital play into science inquiry. Therefore, even if the specific digital game does not allow for open inquiry, the teacher can guide students to collaborate with one another in learning that takes place prior to or after the digital play segment.

In order to stimulate thought and the creation of new conceptual knowledge, analogies are frequently used in science (Braasch & Goldman, 2010). Students are able to create knowledge about new or lesser-known topics through analogical thinking by using their prior knowledge as a foundation (Martin et al., 2019). The use of analogies when linking digital play and scientific inquiry allows students to relate a topic they are already familiar with to the concept they are learning in the classroom. In this method, the idea that students are already familiar with is called the analogy source, and the new concept the teacher is introducing is referred to as the analogy target (Braasch & Goldman, 2010). Therefore, analogies can be very useful tools for teaching students difficult-to-understand concepts (Martin et al., 2019). Since these analogies may be created to assure explicit systematic correspondences in procedures and structures to the target concept, digital play offers a powerful parallel (Vendetti et al., 2015). For example, a good way to make sure that students with varied backgrounds have a shared grasp of the analogy source from which to construct new information is to have the entire class play a digital game before instruction or starting the science inquiry (Martin et al., 2019).

Analogies in digital play can be used during science inquiry in a variety of methods that have been proven to increase student learning (Braasch & Goldman, 2010). For example, the analogy source and target should demonstrate comparable relationships, structures, or processes rather than just superficial or physical similarities (Richland & Simms, 2015). Specifically, if the source and the target have the same appearance or share a feature, then certain things can relate to each other in the source in a way that is similar to how things relate to each other in the target (Braasch & Goldman, 2010). Analogy mapping is a pedagogical strategy to use when directing digital play in order to translate knowledge gained through a game to a comprehension of scientific topics (Martin et al., 2019). This method involves discovering underlying linkages as well as similarities and differences between contexts (Martin et al., 2019; Richland & Simms, 2015).

Students can explicitly map the relationships between the source and the target with the aid of some strategies, including pictures, inquiries, prompts, comparing gestures, and guiding questions (Richland & Simms, 2015). Since they offer images and activities that players or students are likely to remember and may be eager to share with classmates and teachers after gameplay, digital games can be especially helpful in this mapping process (Braasch & Goldman, 2010). The kind of conceptual leaps required for comprehending complex scientific phenomena can be supported by contrasting and comparing the key elements of one system that is well-known (Martin et al., 2019). An example of this method of comparing and contrasting is using a game that has been played repeatedly by the entire class, to those in a second system that is less well-known, such as a new scientific concept (Vendetti et al., 2015). In this instance, teachers use relational analogies from digital games to teach students about the target concepts (Martin et al., 2019). Through the use of analogy mapping, teachers assist students in using their understanding of the primary familiar source, a digital game, to reason and draw new conclusions about a particular science issue.

Martin et al., (2019) describes digital instructional sequences on topics for middle-school science included in the Next Generation Science Standards, which is a set of standards based in the United States (NGSS, 2013). These topics include photosynthesis, heat transfer, and electricity which addresses the crosscutting concept of energy transfer (NGSS, 2013). Martin et al., (2019) outlines existing research that outlines the promise of digital games for creating educational experiences that inspire students to learn subject matter with the same enthusiasm that they learn rules and strategies in well-designed commercial digital games. Digital tools such as these sequences can encourage students' inquiry and thinking (Vendetti et al., 2015). For example, players in the photosynthesis game must create glucose chains in order to propel a robot through a cave (Martin et al., 2019). The player controls a zookeeper in space who must modify the temperature of moving globules sent to warm an egg sufficiently for it to hatch in the heat transfer game (Martin et al., 2019). This digital play can be incorporated into scientific education to help students see their learning in action (Braasch & Goldman, 2010). This opportunity allows students to see the theoretical concepts in a format that caters to their interest since it is present in the form of digital play (Richland & Simms, 2015).

Students can use digital games, such as these instructional sequences as a solid platform to pursue their inquiries on the relevant subject, which they now understand better (Richland & Simms, 2015). As Banchi and Bell (2008) explain, prior to allowing students to start their inquiry, it is necessary that educators equip them with the tools they need to be successful in their individual pursuits. Students may benefit from having the opportunity to practise the necessary skills and apply the foundational knowledge they need to for their inquiries through digital play (Banchi & Bell, 2008). This is because the learning approach of using digital tools can cater to the diverse interests of students and therefore, becomes information they are more likely to retain (Martin et al., 2019). Furthermore, inquiries can emerge from the digital play students engage in that breaks down the difficult science concepts (Richland & Simms, 2015). Since educators have the responsibility of teaching students science concepts, they must recognize students' unique preference of learning, and digital play serves as a familiar and enjoyable means of achieving this (O' Loughlin, 1992).

Martin et al., (2019) goes on to explain the importance of ensuring that teaching aids associated with science inquiry undergo classroom pilot testing and revision in response to instructor and student feedback. Teachers must engage students in group or whole-class activities to support their learning and critical thinking, and concentrate on bringing out their existing understanding of the objective topic rather than their game-specific expertise (Richland & Simms, 2015). It is beneficial to have students describe their prior understanding of the science topic they would be studying in the comparison condition rather than debriefing about the game. Studies that have examined teachers' practices have found that when teachers have explicit discussions about how games are related to instructional content, students perform better (Vendetti et al., 2015). This is true even though many studies of digital games in education place a greater emphasis on game design factors than on teachers' instructional practices (Martin et al., 2019).

2.22 Using role play in scientific inquiry and digital play

Students can actively explore digital content and apply what they have learned through role play. The integration of digital resources and role play assessment provides an engaging hook, as well as good use of time spent online. This dual role of imaginative situations is presented in children's role play and offers opportunity for children to comprehend real-world contexts (Campbell, 2008). This digital play practice can be applied in science inquiries carried out by students.

For example, Campbell (2008) describes digital sources that enable students to build a deep understanding of heredity, a core idea in the life sciences. Stories of scientists who studied genetics are integrated into the curriculum so students learn about the actual methods of scientists which help them to build their understanding of the nature of science. Students engage in scientific inquiry on the biographies of world-renowned scientists through a selection of websites that are approved by the teacher. Giving students the opportunity to investigate the biographies of scientists enables them to engage in guided inquiry as Banchi and Bell (2008) demonstrate.

In guided inquiry, the teacher simply presents the research topic to the students while the approach to investigate and seek explanations is created by the students themselves (Banchi and Bell, 2008). This method of digital play gives students the freedom to explore the lives of scientists who have made important scientific contributions and then transform the information into a role play exercise, enabling them to internalise their findings (Banchi and Bell, 2008). This constructivist learning experience ensures that students are provided the necessary time and opportunities to become active learners to process and reflect on what they are learning through their play (Gulpinar, 2005). Children's socio-emotional development is promoted as they employ roles, connections, and the attendant emotional experiences to form group pretend episodes. To maintain the jointly designed and maintained "as if" reality, a greater variety of metacognitive and self-regulatory behaviours must be practised (Whitebread & O'Sullivan, 2012).

Additionally, when students are given the opportunity to select the scientists they would like to pursue and then apply their knowledge through digital play, they are more likely to gain a deeper understanding of this information as their interest and motivation are piqued (Campbell, 2008; Johnston, 2021). In this specific case, students learn that science is a human endeavour by adding the lives of notable scientists like Mendal, Franklin, Watson, and Crick in the study of genetics (Campbell, 2008). Students are given the option to record their role-play exercise using iPads or Flip Cameras to further engage in digital play. With teacher supervision and assistance, children's digital play and engagement can enhance cognitive development and foster self-regulation, but as before, this must be done with intention, consideration, and awareness (Johnston, 2021).

Students gain a deeper knowledge of the nature of science by being exposed to scientists' actual techniques that are used during the inquiry process (Campbell, 2008). Students' comprehension of important genetics from the past and present might be expanded, and doors could be opened to the study of genetics, with the help of digital content integrated with role-playing in a web-exploration inquiry format (Campbell, 2008; Johnston, 2021). Methods that give students the ability to exercise agency in digital domains and then transfer that knowledge through role playing imaginary situations reflect what Vygotsky (1967) argues as the essence of play and lies at the heart of play.

2.23 Using simulations to connect scientific inquiry and digital play

Effective inquiry learning attempts to strike a balance between student independence and direction and assistance rather than being entirely student-directed (de Jong, 2019). This advice may come from a variety of people, including the teacher, peer students, and, where available, a digital learning environment. Digital play using apps or other small digital tools that scaffold the learner during inquiry processes is one technique to guide and support learners (de Jong et al., 2021).

Chen et al., (2020) describes the benefits of implementing science inquiry through digital game-based learning (GBL), where learners adhere to specific rules to interact with games while continuously receiving feedback. This enables learners to accomplish specific objectives that are frequently built into games as challenges (de Jong, 2019; de Jong et al., 2021). Chen et al., (2020) explains the importance of how teachers facilitating digital game-based learning must take into account the distinctiveness of science as a field, which necessitates not only domain knowledge but also, and more significantly, the epistemic frames underlying the domain. By doing so, students can learn the scientific concepts while overcoming the challenges of the game. The enjoyment that students experience of playing the digital game and pursuing their inquiries allow the learning goals of the lesson and subject concepts to be more memorable (Wien, 2008). This includes ways of knowing in the domain, while designing games, especially instructional aids (Seatter, 2003).

According to de Jong et al., (2021), learners should use science techniques of knowing, which are essentially questions, while playing games. For inquiry learning to be successful, instructional support or scaffolding is required to get students interested in relevant questions (Chen et al., 2020). Through scaffolded instruction, inquiry can help students to demonstrate more conceptual understanding in the post-game assessment, compared with their counterparts. The fact that the using scaffolded instruction in inquiry improved students' game performance is noteworthy as this highlights the importance of pairing proper guidance with student freedom to explore their own predictions. The combination of students learning through their individual scientific inquiry pursuits through their digital play with their teacher's confirmations also contributed to the evaluation following the game (Chen et al., 2020). According to Chen et al., (2020) structured inquiry techniques such as having students predict, observe and evaluate their findings could enhance digital game-based learning and boost both in-game and post-game performance (Chen et al., 2020).

Likewise, Dalgarno and Lee (2010) explore the potential learning benefits of three-dimensional (3-D) virtual learning environments (VLEs). Drawing on published research spanning two decades (Jacobson, 2006), Dalgarno and Lee (2010) identify a set of unique characteristics of 3-D VLEs, which includes aspects of their representational fidelity and aspects of the learner–computer interactivity they facilitate. A review of applications of 3-D VLEs is presented, leading to the identification of a series of learning affordances of such environments (Jacobson, 2006). These affordances include the facilitation of tasks that lead to enhanced spatial knowledge representation. Other factors that the affordances include are greater opportunities for experiential learning, increased motivation/engagement, improved contextualisation of learning and richer/more effective collaborative learning as compared to tasks made possible by 2-D alternatives (Dalgarno & Lee, 2010).

Dalgarno and Lee (2010) contend that the continued development of and investment in 3-D games, simulations and virtual worlds for educational purposes should be considered contingent on further investigation into the precise relationships between the unique characteristics of 3-D VLEs and their potential learning benefits (Dalgarno and Lee, 2010). To this end, they conclude by proposing an agenda or 'roadmap' for future research that encompasses empirical studies aimed at exploring these relationships. Furthermore, future studies could also be aimed at filling the gap that exists. This includes next steps aimed at deriving principles and guidelines to inform the design, development and use of 3-D virtual environments for learning (Dalgarno & Lee, 2010).

Similarly, de Jong et al., (2021) describes the benefits of using (ILSs) Inquiry learning spaces, which are created by teachers with the assistance of an ecosystem called Go-Lab. ILSs are online labs that have been enhanced with tools to support the inquiry process (de Jong et al., 2021). These ILSs are designed around online STEM laboratories (de Jong et al., 2021). Teachers can incorporate these online labs with multimedia resources and learning apps, which are small programs that help students with their inquiry-based learning, within the Go-Lab ecosystem (de Jong et al., 2021). The Go-Lab ecosystem provides schools with pre-made structures like a typical inquiry cycle, alternate scenarios, or finished ILSs that may be used exactly as-is, but it also enables teachers to change these structures to construct custom ILSs (de Jong et al., 2021).

Making abstract qualities explicitly available, as was mentioned in the studies above, is one method to connect the world of experimental activity with the world of theoretical science, which is frequently more textual (Kluge, 2014). The function might be implemented, for example, as students are navigating the different online simulations while using their cursors to select and understand the different scientific terms and concepts (de Jong et al., 2021). It could be created as a layer of abstract textual and numerical information the students can traverse through that is relevant to the visual object, showing, for instance, a hierarchy of scientific relationships and surrounding scientific material, as opposed to just being one piece of information (Dalgarno & Lee, 2010). Given the necessity for dynamics in this information, the teacher should be able to make changes to the material's structure and content (de Jong et al., 2021; Kluge, 2014).

Studies have revealed that students frequently utilize the mouse pointer to explore objects on the screen to explore different terms and scientific concepts through their inquiries (Kluge, 2014). This information search is a means to put the student in the driver's seat, actively seeking out relevant data and engaging with the subject matter (de Jong et al., 2021; Kluge, 2014). The experience students have of actively searching for answers through different means of digital play serves as a factor of interest, therefore they become more engaged in the process (Schulte, 1996; Wien, 2008). In a digital setting, such scientific investigations can be assisted in a variety of ways (Kluge, 2014). Further research is needed to determine how this proximity between the visual, concrete object and the abstract text and number information might be constructed in detail, structurally and contextually, as well as how it might be used (de Jong et al., 2021; Kluge, 2014).

Digital play that includes virtual lab simulations such as the example described above encourages the use of online laboratories as their main teaching tool (Kluge, 2014). These tools include applications that can assist students in formulating hypotheses or designing experiments as well as apps that teach 21st century skills like cooperation and reflection (Christie & Roskos, 2006; Wood, 2013). Deep conceptual knowledge acquisition is often viewed as being fueled by engagement in learning (Johnston, 2021). Engaged learning refers to the deep cognitive processes that students use to transform the knowledge that is presented to them, such as elaborating, abstracting, and relating (de Jong, 2019). In general, the literature agrees that participation in learning clearly correlates with learning that incorporates digital play (Soffer & Cohen, 2019).

Through virtual lab simulations and experiments, digital play can be created to connect scientific theory with a scientific investigation (Johnston, 2021). To close any gaps between a lab experiment and science, three stepping stones and a structure of relevance are found (Kluge, 2014). For the students to remember the outcome of the inquiry, a reference is first required (de Jong, 2019). For instance, the virtual simulation's design can include a layer where students can add their own experiences to the results in order to engage with them on a more theoretical level and contribute material that will improve the results (Kluge, 2014). Giving the students the chance to take responsibility for the outcomes serves a vital purpose (Schulte, 1996; Wien, 2008). The students should also be able to contrast and compare their results with those of other students who conducted the same experiment, which can be done by looking at their own results (Kluge, 2014). As an alternative, simulations that demonstrate some of the same scientific concepts could be used to contrast and compare the experiment (de Jong et al., 2021; Kluge, 2014). Third, a connection to scientific theories is required (Kluge, 2014). Even while the necessary science is present, students may only be able to hazily connect the lab experiments to theory (de Jong et al., 2021; Kluge, 2014). In order to foster the process, the teacher must provide them with scaffolded instruction and supervision as they proceed with their investigation.

2.3 Benefits of digital play and science inquiry

Opportunities for digital play have been recognised in science education programs around the world as vital aspects in helping children retain scientific concepts (Pramling-Samuelsson et al., 2008). Preschool children's readiness to participate in divergent thinking and drive to study science and mathematics may be enhanced when they are given opportunities to explore and create in low-risk scenarios (Vartiainen, 2020). Fleer (2009) explains the relationships between daily notions and scientific concepts in children's playful contacts. Fun learning environments can help students understand scientific concepts, and that playful events can offer conceptual spaces for the interlacing of ordinary and scientific notions (Vartiainen, 2020). In a play-based environment that allows students to engage with digital tools, children display different and dynamic levels of thinking (Fleer, 2009).

Through my experience as a virtual Kindergarten teacher, I observed children playing with different materials and exploring scientific concepts, such as the different states of matter. I have seen children play in low-risk environments while being provided with digital tools necessary for their inquiries. Children use these tools to experiment and understand the difference between liquids and solids by playing at the water station and lego station. In these contexts, it is very apparent that children are enjoying themselves while playing with the different approaches that are provided and even express their happiness when they are called to each station. Banchi and Bell (2008) describe similar observations of children fully engaged in hands-on activities that allow them to make predictions and then see what actually takes place. Furthermore, after performing different forms of assessments, it was evident that many of the children were able to gain a better understanding of the concepts that they were taught and were able to recall the vocabulary even weeks after their play experience (Banchi & Bell, 2008).

One benefit of integrating digital play in scientific inquiry is that children are offered opportunities for real meaning-making. The formation of communal scientific narratives together with shared wonderings is a vital component of play-based science education (Fleer, 2019). Following a sociocultural perspective on play, studies show that play is evolving through a process in which a child's psychological functioning, as well as his or her social and material circumstances, collide and work together for the child to make sense of the scientific concepts they are exposed to (Fleer, 2019; Jacobson, 2006).

Play and imagination are crucial to the real meaning-making process in which children develop science practices and knowledge socially and culturally in this approach, rather than being limited to just motivators of science activities (Vartiainen, 2020). Since children are naturally curious to learn about how the world works through testing and investigation, imaginary science settings may emerge from children's daily curiosity about scientific events and desire to study (Eshach & Fried, 2005). In fictional scientific settings, children can play the role of a scientist and act like scientists do (Andrée & Lager-Nyqvist 2013). Through these experiences, scientific play elicits good emotions in the children, which is an important aspect of meaning creation and learning (Vygotsky 1978). Material items, such as scientific accessories and science equipment, are also recognised as crucial fun pivots that spark and maintain the scientific play of young children (Vartiainen, 2020). Moreover, digital platforms with virtual lab simulations, for example, that provide students the opportunity to experiment allows children to truly let their play experience grow an appreciation for science.

Another advantage of integrating digital play in science inquiry is that it plays a significant role in creating favourable attitudes towards science. Children develop enjoyment from watching and learning about the nature and usage of scientific terminology in the kindergarten curriculum (Eshach & Fried, 2005). Early introduction to science can stimulate scientific thinking and improve knowledge of science when it is studied more formally in higher grades (Watts et al., 2017). In fact, there are considerable similarities between children's natural dispositions to play and the finest methods of science learning (Inan et al., 2010). There are three main approaches of using play to teach science which include experimenting, hypothesising and reflection (Vartiainen, 2020). Children can ask, "I wonder what will happen if...?" while experimenting in order to feed their inquisitive minds therefore, will feel intrigued and want to find answers. When hypothesising, children reason by saying “If I do this..., the following will happen because...,” which is how children appear to reason (Vartiainen, 2020). Finally, as children reflect, they build connections between old and new experiences to demonstrate their learning and can even communicate their comprehension of the concepts they learned (Vartiainen, 2020). “Where have I seen this before?” and “From where do I recognise it?” are some of the queries they ask. Children notice and differentiate numerous elements of items and materials when exploring and examining (Vartiainen, 2020). Furthermore, when children are offered these opportunities through digital play it allows them to develop additional skills that are needed. Students are not only becoming critical thinkers and growing inquisitive minds, but also becoming familiar with technological skills through experimenting with different forms of digital play.

Overall, it is necessary to understand what ideas students are already coming into the classroom with before starting to introduce scientific topics. Teachers must acknowledge that students are diverse and come with unique life experiences and different styles of exploration from which they navigate the world around them (Qualter et. al, 1990). It is from these unique experiences that students construct their beliefs which teachers can use as a learning opportunity. This can serve as a means to implement an emergent curriculum which incorporates the constructivist learning paradigm (Wien, 2008). That being said, students are responsible for their learning, since their pre-existing ideas and life experiences. This can create rich learning for students when they make the connections to the new information they are discovering and being presented with (Seatter, 2003). Therefore, teachers can create meaningful activities which can help students rebuild their ideas and thinking through open science talk, collaboration, and testing their ideas. This ongoing process of learning needs quite a bit of work from both teachers and students, each responsible for the learning taking place.

3. Conclusions

3.1 Implications for this Research

Although there are several benefits with integrating digital play into science inquiry, there are a number of challenges that may exist. For example, a science teacher who is conscious of following a predetermined curriculum, may be concerned that student-initiated play would be thought of as a distraction from the more formal lesson material of the science curriculum and therefore, teachers may avoid providing students with play opportunities (Andrée et al., 2013). Goldhaber (1994), who looked at example narratives of real-world kindergarten instruction, found that Early Childhood Educators were concerned about not having enough time or resources, and that play was not seen as a main learning medium. Furthermore, preschool instructors raised concern over whether or not children should be permitted to play, if the activity is to be labelled under scientific inquiry (Goldhaber, 1994).

Additionally, teachers work with restricted time frames where they have to meet deadlines, such as the end of the school term and report card seasons. On top of this, some schools enforce standardized testing which adds more stress and pressure for teachers to address certain scientific concepts within short periods of time (Haney & McArthur, 2002). As a result, following a more traditional teaching style may seem more convenient especially because constructivism does require more time for students to first acknowledge their prior ideas, discuss and share those pre-existing ideas with the class, then work through problem solving activities that allow them to adapt to the new ways of thinking they have just acquired (Hodson, 1998). Students must acknowledge the importance of scientific literacy so that they are well versed in the language and can discuss their ideas with one another more freely.

Furthermore, the curriculum requires students to grasp theoretical concepts such as outer space or gravity which are more challenging to explain to students through their exploration (Kenny, 2010). According to Seatter (2003), such theoretical concepts cannot be discovered independently unless teachers directly teach and explain the scientific ideas to the students. Teachers may find it more effective to simply teach students these topics for time efficiency and practicality sake (Seatter, 2003). In order to provide more theoretical context, direct instruction and more frequent teacher intervention may seem to be the more efficient method (Knaggs & Sondergeld, 2015). Teachers may find the traditional teaching method more convenient for this reason as well. However, resources such as professional development can help teachers become more familiar with the different levels of inquiry (Seatter, 2003). This can prevent teachers becoming overwhelmed with the idea of including student inquiry in science classrooms as a common misconception may be that scientific inquiry only includes open inquiry, where students are required to develop questions, plan and conduct research, and present their findings (Knaggs & Sondergeld, 2015).

3.2 Next Steps

In order to combat the challenges yet reap the benefits of using a constructivist learning model in science instruction, teachers must use their judgement to maintain an effective balance between having students be active participants in their learning, and delivering direct instruction. According to Seatter (2003), science education requires a well-balanced constructivist approach. This entails teachers helping students develop a mindset to understand that different constructions of knowledge, including ones from life experiences and social interactions are required to make sense of new learnings. This notion of being open to learning something new, while reflecting on pre-existing ideas can enhance the overall learning experience for learners (Seatter, 2003). Students can benefit from understanding this learning model so that they can be mindfully aware of the connections that they are making. This way students can prepare themselves to understand that their prior way of thinking was not wrong, but make the connection to their new learning which results in them feeling more competent and confident (Schulte, 1996).

Children's play promotes the development of cognition, language, self-regulation and collaboration (Nicolopoulou et al., 2009). Therefore, examining play as an intrinsic part of everyday classroom practice may provide fresh insight into science learning processes. Digital play helps children retain concepts, offer opportunities for meaning-making, and create positive attitudes towards science. Exploratory play in scientific fields can enhance young children's natural curiosity providing a healthy foundation for future learning. When educators allow students to share their ideas on scientific topics prior to introducing the concepts to them, students are inclined to make connections to their lived experiences making the learning more memorable (Haney & McArthur, 2002). Furthermore, to avoid students feeling unhappy about having preconceived beliefs that were not accurate, teachers can guide students to develop an open mindset to adapt their way of thinking (Seatter, 2003). Giving students opportunities to engage in science inquiry through digital play would be beneficial since teachers would be maintaining a balance of direct instruction and active learning that reflects the emergent curriculum teaching practice (Edwards et al., 2012).

Effective scientific teaching and learning through digital play helps children retain concepts, offers opportunities for meaning-making, and creates positive attitudes towards science. Exploratory learning through digital platforms in scientific fields can enhance young children's natural curiosity providing a healthy foundation for future learning. Furthermore, children's grasp of academic topics in later schooling and life can be aided by their early mastery of scientific concepts. This is an opportunity that should not be overlooked and more time for scientific inquiry through digital play should be offered in classrooms.

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