A Carbon Literacy for Green Innovation and Entrepreneurship Humanoid Robot-Assisted Digital Storytelling Model

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I am solely responsible for this research endeavour, except for summaries and quotations that have been appropriately referenced.

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Abstract

Climate change has been negatively impacting our environment. The adverse effects of climate change include flooding, drought, rising sea levels, hurricanes, and high temperatures in different regions. The primary source of climate change is the release of greenhouse gases into the atmosphere. Methane (CH_4), nitrous oxide (N_2O), and carbon dioxide (CO_2) are examples of greenhouse gases. Specific human activities contribute to the emission of greenhouse gases into the atmosphere. Fossil fuel combustion is the primary human activity responsible for greenhouse gas emissions. Carbon dioxide is the most prevalent greenhouse gas, accounting for approximately 75% of global emissions. This dominance of carbon dioxide in greenhouse emissions necessitated the concept of carbon literacy to educate individuals and organizations on ways to reduce their carbon footprint.

Robot-assisted digital storytelling is a digital storytelling method that uses social robots to tell a story to audiences. From elementary schools to universities, robot-assisted storytelling has been demonstrated to be an effective teaching method. However, no published model exists for developers to create robot storytelling instruction or training. Hence, this thesis proposes a robot-assisted digital storytelling model for carbon literacy training. The study employed the design science research methodology for its activities.

The model development process started with the selection of articles that had been published on robot storytelling. The selected articles were analyzed, and the procedures and activities used to create robot storytelling were identified. Those activities and procedures were synthesized to develop the proposed robot storytelling model. The model was experimented with by using it to create digital storytelling, which trained selected undergraduate students on carbon literacy. Similar training was delivered to some students using a narrated PowerPoint presentation for comparison. The two pieces of training were evaluated, and it was discovered that though both trainings improved learning outcomes and motivation, the robot storytelling enhanced the participants' knowledge of carbon literacy better than the narrated PowerPoint presentation. In conclusion, this study proposed a six-element model that enhances learner motivation, engagement, and learning outcomes in carbon literacy training.

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Publications From This Thesis

1. Essien, G. and Parbanath, S., 2024. Exploring the World of Robot-Assisted Digital Storytelling: Trends, Models, and Educational Implications. *Journal of Information Technology Education: Research*, *23*, p.027.

2. One paper was presented at the Climate Change and Economic Management for a Sustainable Future Conference, organized by the DUT Business School on 26 February 2025, at the Coastlands Umhlanga Hotel, and is pending publication. The title of the paper is "Improving Undergraduate Students' Understanding of Carbon Literacy through the Use of Robot-Assisted Digital Storytelling".

3. A third paper has been presented to the Australasian Journal of Educational Technology (AJET) and is in the pre-review stage at the time of submitting this thesis for examination. The title of the paper is "A proposed robot-assisted digital storytelling instructional model to develop robot storytelling instruction that enhances undergraduate students' carbon literacy knowledge".

4. A fourth paper titled "Digital Storytelling in Higher Education: A Systematic Analysis of Platform Usage, Instructional Benefits, and the Implications for Teaching and Learning" has been presented to Computer Assisted Language Learning Journal, and it is in the pre-review stage at the time of effecting corrections after external review.

CHAPTER ONE

Introduction to the thesis

This chapter provides an overview of the thesis's topic, including a brief introduction to climate change and its environmental impact, as well as an exploration of digital storytelling concepts. It also states the thesis statement, the statement of the problem, the aim, the objectives, and the research questions that guided this thesis. The chapter further explains the motivation that encouraged the researcher to undertake this study, the thesis's contribution to the field of robot storytelling, and finally, how the thesis report was organized.

1.1 Background

Climate change has been one of the most critical concerns confronting most governments worldwide (Cimato & Mullan, 2010). Various governments and organizations have recognized the importance of educating individuals and the general public about the causes and consequences of climate change. Greenhouse gases (GHGs) emitted into the atmosphere constitute the leading cause of climate change (Decisions, 2010). Carbon dioxide is the prime greenhouse gas (GHG) contributing to climate change (Decisions, 2010). As a result, the general populace requires carbon literacy instruction to be abreast with knowledge on carbon footprint and how to reduce it (Molthan-Hill & Winfield, 2023). Digital storytelling is a teaching/learning technique that can be utilized to implement carbon literacy education. According to studies, robot digital storytelling (R-DST) learning strategy promotes learning accomplishment, attitude, critical thinking awareness, and satisfaction (Chang *et al*., 2023). However, there is insufficient literature on creating robot-assisted digital storytelling (Essien & Parbanath, 2024). Therefore, further research is needed on a model that will aid educators in creating robot-assisted digital storytelling. In light of that, this study is developing a robot-assisted digital storytelling model for carbon literacy training. The following subsections provide further discussion of the thesis's background.

1.1.1 Climate Change and Carbon Literacy

According to Tadesse and Dereje (2018), climate change is any notable change in weather patterns that occurs in a location over an extended period. The production of GHGs into the atmosphere is responsible for climate change (Decisions, 2010). GHGs absorb heat into the Earth's atmosphere, a phenomenon known as the greenhouse effect (Adedeji *et al.,* 2014). The three primary gases contributing to the greenhouse effect are carbon dioxide, methane, and nitrous oxide (Adedeji *et al.,* 2014). According to Nda *et al*. (2018), carbon dioxide is the most crucial component of GHGs because it accounts for roughly 75 percent of the country's total emissions. The emission of GHGs into the atmosphere is primarily caused by activities carried out by humans (Decisions, 2010). The activities include the combustion of fossil fuels, including coal, natural gas, and petroleum, all of which contribute to carbon dioxide emissions into the atmosphere (Decisions, 2010). Deforestation and agriculture are also human activities that produce methane and nitrous oxide into the atmosphere (Tadesse & Dereje, 2018). Climate change has led to several significant effects, including droughts, hurricanes, rising sea levels, flooding, and increased temperatures worldwide (Adedeji *et al*., 2014).

Governments and organizations worldwide believe that educating people on the impact of carbon dioxide in the ongoing climate change problem will be a good way to tackle the menace. This education brought about the term carbon literacy. Carbon literacy is the knowledge of climate change and its impact on humanity's everyday actions (Handwiki, 2022). Howel (2018) also defined carbon literacy as an individual's ability to find, comprehend, and assess the pertinent information required to make decisions while being aware of the anticipated effects of GHG emissions. Education focused on carbon literacy enables individuals and businesses to identify the most effective methods for mitigating the adverse effects of climate change and reducing their carbon footprint (Decisions, 2010). A carbon footprint is the total amount of GHGs released into the environment by an individual, organization, event, or product (Decisions, 2010). These emissions might be created directly or indirectly. Achieving this knowledge of best practices requires consciously educating the masses on carbon literacy. This study will, therefore, employ robot storytelling for carbon literacy education to promote environmentally friendly activities and services, thereby fostering sustainable development, which is reflected in the thesis title's use of the term 'Green Innovation'. As stated by Xiao and Fei (2024), "green innovation" refers to technical advancements that reduce their environmental impact, enhance the efficiency with which resources are utilized, and promote sustainable growth.

1.1.2 Humanoid and Social Robots

A humanoid robot is characterized by a body shape similar to that of a human (Kajita *et al*., 2014). Humanoid robots can move either with a bipedal locomotion system or a wheeled system (Saeedvand *et al.,* 2019). According to Saeedvand *et al*.'s 2019 research, bipedal robots are more suited for navigating complex workplaces. Humanoid robots can communicate using speech, facial expressions, gestures with their arms and hands, gazing, and other forms of body language. Humanoid robots can grasp objects with their hands and perceive their surroundings with the aid of sensors, allowing them to see and hear. In 1973, Professor Kato and his colleagues at Waseda University in Tokyo, Japan, were responsible for constructing the first humanoid robot (Kajita *et al*., 2014). Wabot-1 was the name given to the first humanoid robot designed by Kajita *et al*. (2014). It could walk on its two legs and grasp objects with its hands. Professor Kato and his team built their second robot in 1984, named it Wabot-2. Wabot-2 robots could play the piano (Kajita *et al.,* 2014).

Humanoid robots work as teaching assistants in instructional delivery. They can also entertain Kindergarten children and older adults. Other fields where humanoid robots are employed are industry, space exploration, and healthcare delivery. In hospitals, humanoid robots assist nurses and patients in their activities (Ting *et al*., 2014). In industry, they carry out tasks such as welding, which otherwise could be dangerous for humans (Ting *et al.,* 2014). Humanoid robots can work in homes as guards. In businesses, humanoid robots work as customer service agents in retail stores. Examples of humanoid robots are Nao, DARwIn-OP, Open-HRP, and iCub (Saeedvand *et al*., 2019).

According to Campa (2016), a social robot is an autonomous, physically embodied agent that communicates emotionally and interacts with people in a social context. They can engage with people in a human-centric manner and function in contexts inhabited by humans (Breazeal *et al*., 2016). Social robots can have either a humanoid nature or an animaloid appearance (Sendari *et al.,* 2015). Although there are differences in the form of social robots, they share a common characteristic. They share common qualities, such as interacting with people in an interpersonal manner, communication, and coordinating their behaviour with humans using verbal, non-verbal, or affective modalities (Breazeal *et al*., 2016). People who interact with social robots tend to perceive them as having human characteristics. This perception is termed anthropomorphism. There is a correlation between applying anthropomorphic concepts to the design of robots' physical appearance and their movement, reaction, and interaction with people (Fink, 2012). This correlation helps to ease user contact and adoption. According to Fink (2012), anthropomorphism refers to a person's tendency to attribute human characteristics to items that lack a lifelike appearance. This thesis will employ a humanoid and social robot called Nao for digital storytelling.

1.1.3 Digital Storytelling

According to Smeda *et al.* (2014), digital storytelling is creating and telling a tale using various digital media elements, including text, graphics, animation, audio, and video. Many authors have defined digital storytelling differently, but all the definitions revolve around the same idea as the one described above. One of the definitions of digital storytelling proposed by Robin (2016) is that it blends the art of storytelling with various types of media, including photographs, recorded narration, music, and video. In addition, Sage *et al*. (2018) defined digital storytelling as the conveyance of a narrative through digital technologies and media, including, but not limited to, audio, video, art, graphics, pictures, and text. Digital storytelling began with the invention of the digital computer, which enabled the creation of digital media elements. Before the digital computer era, traditional storytelling was the primary means of sharing stories. Traditional storytelling conveys concepts, beliefs, life experiences, and lessons through narratives or stories that evoke strong emotions and profound insights (Serrate, 2008).

According to Tenh *et al*. (2012), the late Atchley, a media producer and multidisciplinary artist, was the first to initiate the concept of digital storytelling.
"Next Exit" is the name of the multimedia autobiography and the first digital story that Atchley created. Lambert and Atchley transformed the autobiography into a digital tale (Lambert, 2013). The primary purpose of digital storytelling is to convey information or knowledge to a target audience. Instructors utilize digital storytelling to communicate academic knowledge to schoolchildren and disseminate information to the broader community. Business owners use digital storytelling to engage and assist customers in retail settings. In hospitals, management utilizes digital storytelling to provide patients with directions and engage them. According to Robin (2016), digital storytelling is used in museums to provide information about exhibition items, answer questions about the exhibits, and engage visitors in the subjects being presented. Additionally, businesses utilize digital storytelling to promote their products to the general public through the Internet (Robin, 2016).

Robin (2006) categorized digital storytelling into three primary types: personal narratives, historical documents, and informational or instructional stories. According to Robin (2006), personal narratives feature recounts of key life events. Historical documentaries are narratives that investigate significant events, aiding in our understanding of the past (Robin, 2006). The third type of digital storytelling is designed to educate or train the audience on a specific concept or technique (Robin, 2006).

Digital stories can also be categorized based on the platform used to present the story to the target audience or viewers. These categories include robot-based or robot-assisted, social media, web-based, computer-based software, and mobile device software platforms (Frazel, 2010; Miller, 2020). The web-based digital storytelling platform utilizes a video hosting site or a story creation site, allowing users to visit the site to watch video stories or create their own (Frazel, 2010; Miller, 2020). Mark Ury established the Story Bird website in 2010, an example of a web-based digital storytelling creation site

(Kazazoglu & Bilir, 2021). These web-based or online digital storytelling sites may also feature prerecorded storytelling using various platforms, such as robot storytelling (Frazel, 2010; Miller, 2020). These sites may also host digital storytelling sessions. A computer-based software platform for digital storytelling presents a story to viewers using video or presentation software on a computer. According to Essien and Parbanath (2024), digital storytelling systems that are robot-based or robot-assisted present viewers or listeners with a narrative through the use of social robots. Some social robots (e.g., Pepper robots) have screens that can display videos and images to viewers (Pandey & Gelin, 2018). Some social robots also use gestures and gazing while presenting stories to people and displaying images or videos (Pandey & Gelin, 2018). According to Ham *et al.* (2015), because of these qualities, social robots can capture listeners' attention and maintain their interest throughout the storytelling process.

Some experts in the field of digital storytelling have published conceptual models for creating digital storytelling. These models contain information on the development process of digital storytelling to guide developers. This information is referred to as model elements. Therefore, digital storytelling models visually present elements for creating and sharing digital stories.

1.2 Thesis statement

A Robot-Assisted Digital Storytelling Model can enhance learner engagement, motivation, and learning outcomes in Carbon Literacy for Green Innovation and Entrepreneurship (CL4GIE) training.

1.3 Statement of the problem

According to Robin (2016), digital storytelling is becoming increasingly popular in various professions and areas of human life, including education and healthcare. Experts in digital storytelling have proposed different models for creating digital storytelling. An example is Porter's model (Kogila *et al*., 2020). This model comprises six elements: "living in your story, unfolding lessons learning, developing creative tension, economizing the story told, showing not telling, and developing craftsmanship" (Kogila *et al*., 2020). Porter's model recommends that a story should teach a lesson and, from the beginning, put viewers in a state that makes them anticipate certain events in the story flow. The model also suggests that the narrative incorporates fewer media elements to communicate its meaning effectively. Lastly, the story should involve images to reduce the amount of narration. However, the model is silent on requirement analysis and evaluation, which are necessary elements in software modules meant for training or lesson delivery. Additionally, Porter's model did not mention hardware, software, or multimedia elements, which are essential components of digital storytelling.

However, a new trend in digital storytelling is using robots to implement the storytelling. The authors Conti *et al.* (2020) utilized this emerging trend in storytelling by employing a robot to narrate a story to kindergarten students and comparing it to the storytelling that humans perform. They discovered that the children could memorize the robot's story better than the human storyteller's. According to Chen Hsieh (2021), robot-assisted digital storytelling is gaining popularity because it attracts learners' attention and sustains their interest, thereby improving learning outcomes. The robot's gestures made the experience even more enjoyable. As a result of those robots' features, social robots are being used to assist teachers in educating children in Japan and elsewhere (Iio *et al*., 2019). Despite the positive impacts of robot-assisted digital storytelling, there are inadequate models for developers (Essien & Parbanath, 2024). A robot-assisted digital storytelling model serves as a guide for developers in organizing and creating robot storytelling. According to Essien and Parbanath (2024), the only published model for robot storytelling that assists developers of robot storytelling does not contain all the relevant elements for developing robot-based storytelling for training or instructional delivery. Against this backdrop, this study suggests developing a robot-assisted storytelling model that incorporates all pertinent aspects of robot storytelling for carbon literacy training, serving as a guide for developers creating robot-assisted digital storytelling for instructional delivery.

1.4 Research questions

The research questions that directed this investigation are as follows:

1. How can a robot-assisted digital storytelling model be developed based on existing research in robot storytelling to enhance learner motivation, engagement, and learning outcomes in carbon literacy for Green Innovation and Entrepreneurship (CL4GIE) training?

2. How can the proposed robot-assisted digital storytelling model be validated?

3. How can the proposed robot-assisted digital storytelling model be experimented with to train selected undergraduate students in carbon literacy?

1.5 Research aim and objectives

The research aims to develop a humanoid robot-assisted digital storytelling model for creating robot storytelling that enhances learner motivation, engagement, and learning outcomes in carbon literacy for green innovation and entrepreneurship (CL4GIE) training.

The specific objectives are:

i. To identify digital story elements (DSEs) required for a robot-assisted digital storytelling model that enhances learner motivation, engagement, and learning outcomes in carbon literacy for green Innovation and entrepreneurship (CL4GIE) training.
ii. To develop a robot-assisted digital storytelling model incorporating the identified digital story elements.
iii. To evaluate the model's performance for enhanced learner motivation, engagement, and learning outcomes in CL4GIE training.
iv. To compare the implementation of robot-assisted digital storytelling for CL4GIE training to computer-based digital storytelling for CL4GIE training.

1.6 Motivation

The carbon literacy project is a British Council-funded project for some selected universities, which is being managed by Durban University of Technology (DUT) (DUT, 2021) in cooperation with The University of Sheffield Hallam (United Kingdom), Kisii University (Kenya), Ladoke Akintola University of Technology (Nigeria), and Innovate Durban (South Africa) (DUT, 2021). The project has two distinct goals, which are as follows (DUT, 2021). First, the project aims to enhance the capability of the selected universities to engage and offer significant contributions as pivotal participants in the Green Innovation and Entrepreneurship Ecosystems (GIEEs) within their respective nations (DUT, 2021). Secondly, the project aims to strengthen GIEEs and enhance the capabilities of sub-Saharan African youths to capitalize on GIE opportunities for employability and job development (DUT, 2021).

The Durban University of Technology and its colleagues advertised the project to admit committed postgraduate (Master's and Doctoral) and postdoctoral students across departments within the university (DUT, 2021). These students should be interested in engaging in research and innovation within partner institutions across diverse research domains, including Carbon Literacy Digital Storytelling (DUT, 2021).

Following the advertisement above and the researcher's desire to pursue a PhD, the researcher was admitted to undertake this thesis, which aims to develop a robot-assisted digital storytelling model and implement it using a Nao humanoid robot.

1.7 Contributions

The thesis's contribution to the digital storytelling domain is to develop a robot-assisted digital storytelling model that enhances learner motivation, engagement, and learning outcomes, guiding robot storytelling developers in education and other sectors. The model has six elements that guide developers: storytelling requirements, preparation, programming, testing, delivery, and assessment. In addition, the study utilized the proposed model to create robot-assisted digital storytelling, training selected undergraduate students on carbon literacy and enhancing their knowledge in this area.

The research also made the robot programming code available to researchers for use as a reference in creating other robot storytelling instructions.

1.8 Organization of the thesis

Chapter One – Introduction to the Thesis

The chapter provides the context of the topic, including the thesis statement, study problem, guiding questions, aim and objectives, motivation, contributions, and the report structure.

Chapter Two - Literature Review of the Thesis Topic

This chapter first reviews pertinent literature on digital storytelling before conducting a scoping evaluation of robot-based storytelling and related models to establish the gap addressed in this thesis.

Chapter Three – An Overview of Humanoid Robot Technology

This chapter provides an overview of the design principles for humanoid robots, encompassing design mechanisms, kinematics, control, sensors, programming, and other relevant aspects.

Chapter Four – Methodology for the Research

The methodology chapter examines the core principles guiding the creation of the thesis, the research methodologies employed, and the ethical considerations pertinent to this study.

Chapter Five - Robot-assisted Digital Storytelling Model for Carbon Literacy Training

This chapter describes the development of the proposed robot-assisted digital storytelling model, followed by an expert review.

Chapter Six – Model Experimentation, Results, and Discussion

This chapter covers the experimentation and user-based evaluation of the robot storytelling model on carbon literacy training.

Chapter Seven – Research Conclusion, Limitations, and Recommendations

The chapter summarizes the thesis work, states limitations, and makes recommendations.

CHAPTER TWO

Literature Review of the thesis topic

This chapter provides an overview of digital storytelling (DST), explores various platforms for its creation, and reviews conceptual models associated with it. The chapter also provides a scoping assessment of robot storytelling models to identify patterns and deficiencies in the models and their implications.

2.1. Digital storytelling (definition, origin/history, types, uses)

Researchers in digital storytelling (DST) have provided many definitions of digital storytelling. Robin (2016) defined DST as the art of merging storytelling with a combination of digital media elements, including text, photographs, recorded audio narration, music, and video. According to Robin's (2016) paper, DST consists of short stories that span 2 to 10 minutes and utilize various digital media elements. Robin and McNeil (2019) also described DST as a movie-making technique that combines digital artifacts to produce short movies, including photos, text, video clips, animation, and music. Another researcher defined DST as the art and craft of studying various forms of media and software applications to communicate stories through digital media in innovative and powerful ways (McLellan, 2007). In addition, Smeda *et al*. (2014) defined DST as the use of various multimedia tools and components, such as animation, audio, video, and graphics, to tell a tale. Rossiter and Garcier (2010) provide an additional definition of DST, arguing that it comprises brief vignettes that integrate storytelling through multimedia artifacts such as photographs, audio, and video materials. Sage *et al.* (2018) described DST as conveying a narrative through various digital media, including audio, video, art, graphics, images, and text. All the definitions described above revolve around the same idea of using one or more multimedia elements to tell a story without taking into consideration the platforms for creating and sharing the stories. In light of this, the study proposes the following definition for digital storytelling. Digital storytelling is the art of combining media elements, such as text, images, audio, and video, to create and communicate digital stories on software or hardware platforms. This definition encompasses all platforms for creating digital stories, including robots, computers, smartphones, and online platforms.

During the 1980s, Dana Atchley was credited with developing the concept of digital storytelling, as stated by McLellan (2007). Dana Atchley, a performer who tells stories, started incorporating multimedia into his performances as a prop and adopted various storytelling approaches in multiple ways. According to McLellan (2007), he utilized software tools to build and narrate stories through cinema, video, music, and photography, and to fashion a fresh show for each performance. Atchley's storytelling performance centred on telling stories over a campfire (McLellan, 2007). During that narrative, he incorporated a digital campfire displayed on a small television screen. It was surrounded by actual logs, images, stories, family photographs, and videos that he wove together to create an emotionally powerful tapestry of life stories (McLellan, 2007). Atchley and Joe Lambert spent the 1990s exploring their mutual interest in digital stories (McLellan, 2007). Atchley and Lambert were among the media artists, designers, storytellers, and theatre professionals in the San Francisco Bay Area who participated in this endeavour. Due to this mutual interest, the Centre for Digital Storytelling (CDS) was established in Berkeley, California (McLellan, 2007). The CDS is the most prominent global organization promoting digital storytelling. It provides training to individuals on how to create short media pieces by combining digital image and video editing tools (McLellan, 2007).

According to Robin (2006), digital storytelling can be categorized into three main types: personal narratives, historical events, and instructional or enlightening stories. Personal narratives encompass people's life experiences, including travel, tourism, education, marriage, festivals, and the working environment. Historical events are presented through digital storytelling, highlighting key moments from the past. Historical events encompass the history of an ethnic group, providing insight into their origins and culture. The group consists of people in a community, a country, institutions, or organizations. Digital stories that inform or instruct include stories used to educate people and advertise business information. This type of digital storytelling has gained popularity in educational institutions from kindergarten to university levels. Instructors at various academic levels are utilizing digital storytelling as an instructional tool to deliver lessons to school pupils and students. Businesses also use digital stories to inform potential customers about goods and services.

According to Robin and McNeil (2019), people use digital storytelling to present new material, facilitate discussion, and make abstract content more understandable. Students utilize digital storytelling to prepare their work, thereby becoming more creative and skilled in expressing their opinions (Putri, 2018). Moreover, online digital storytelling allows students to showcase their work digitally and exchange ideas with their peers (Papadimitriou et al., 2013). Digital storytelling is used in educational institutions, communities, and organizations to educate members on pertinent issues, such as climate change (Otto, 2017).

Businesses utilize digital storytelling to promote their products to potential customers through social media (Coker *et al*., 2017). Numerous organizations leverage internet platforms, such as Facebook, X, and Instagram, to market their products and services to prospective customers (Charan & Bansal, 2016). Digital storytelling, typically in the form of short videos, is prevalent on these social media platforms (Coker *et al*., 2017).

Digital storytelling is utilized in healthcare delivery to share vital health information and educate individuals about various diseases. Hospitals employ digital storytelling to provide electronic information on numerous diseases and their associated symptoms. For instance, hospitals create videos featuring people suffering from diseases such as malaria and tuberculosis, along with their corresponding symptoms, to educate the public about these conditions.

Digital storytelling is used in museums to provide tourists with information about exhibition items, answer questions about the exhibits, and engage tourists in discussions about cultural backgrounds (Robin, 2016).

2.1.1. Platforms for creating digital stories

Digital storytelling platforms are software or hardware infrastructure that enable the creation and sharing of digital stories with audiences. Such platforms include social robots, social media, online or web-based, computer-based, and mobile device software. The following are descriptions of these platforms.

2.1.1.1. Robot-assisted/Robot-based platforms

Robot-assisted platforms are social robots that narrate stories to people. Social robots are autonomous entities that emulate human thought and behaviour, enabling unrestricted interaction with people (Lee, 2020). Social robots can be humanoid or animaloid (Sendari *et al*., 2015). Examples of social robots include the Pepper robot (Allan & Bartneck, 2022), Nao robot (Seo & Robotics, 2013), Asimo robot (Hirose & Ogawa, 2007), Kebbi air robot (Chen Hsieh & Lee, 2023), Sota robot (Gota *et al,.* 2020), and Haru robot (Gomez et al., 2018). The following are descriptions of popular social robots used for storytelling.

Nao Robot: Nao Robot is a humanoid social robot developed by Aldebaran Robotics. Aldebaran Robotics initiated the Nao robot project in 2005 (Seo & Robotics, 2013). The Nao robot has participated in RoboCup since 2008 at the competition held in Suzhou, China. In 2009, 24 teams participated in the RoboCup competition utilizing 100 Nao robots (Seo & Robotics, 2013). Nao robots possess 25 degrees of freedom (DoF) and exhibit bipedal locomotion (Deutsch *et al*., 2011). A processor is situated in its chest, capable of reading all sensors within an 8-millisecond cycle period (Deutsch *et al*., 2011). Nao robot has its central processing unit in its head, which runs on the Gentoo Linux operating system (Deutsch *et al*., 2011). Nao measures 57.3 cm in height, 27.3 cm in width, and weighs 5.6 kg (Seo & Robotics, 2013). Nao's body is made of plastic and features a 21.6V 2Ah lithium-ion battery, providing 90 minutes of operational power (Seo & Robotics, 2013). Nao can connect to a computer by either wired or wireless methods. Numerous Nao robots may communicate using infrared sensors, a wireless network, a camera, a microphone, and a speaker (Seo & Robotics, 2013). Nao is programmed using a specialized NAOqi framework, which enables communication between motion, audio, and video modules (Seo & Robotics, 2013). Nao users employ an intuitive graphical user interface programming software named Choregraphe to develop apps for controlling Nao's functions (Seo & Robotics, 2013). The monitor is a program installed alongside Choregraphe, providing Nao with feedback and simple access to its camera settings (Amirova *et al.,* 2021). Nao has two cameras, two speakers, and four microphones that provide directional feedback (Seo & Robotics, 2013). The current version of the Nao robot is version 6, which supports 20 different languages (Amirova *et al*., 2021). Figure 2.1 shows the image of the Nao robot.

Figure 2.1: Nao Robot (Goldman *et al.,* 2023)

ASIMO Robot: ASIMO is an autonomous humanoid robot developed by Honda Motor Corporation. ASIMO represents a significant advancement in innovative mobility, serving as the collective designation for all of Honda's humanoid robots (Hirose & Ogawa, 2007). It is 120 cm tall, 45 cm wide, and weighs 52 kg (see Figure 2.2). ASIMO's width enables it to pass through narrow doorways and corridors. Its legs are 61cm long, allowing it to go up and down stairs (Hirose & Ogawa, 2007). ASIMO is a bipedal robot equipped with a frame grabber for image processing, voice recognition, and synthesis capabilities, as well as a processor for control and planning (Sakagami *et al*., 2002). Two cameras are mounted on the head unit to capture stereo pictures for depth computation, and two microphones for sound recognition are positioned on the front of the helmet (Sakagami *et al*., 2002). These cameras allow ASIMO to identify images from both distant and close proximity. The system incorporates facial image recognition capabilities, enabling face detection, direction estimation, and identification irrespective of the individual's position inside the camera's field of view (Shigemi *et al*., 2018). The robot can recognize speech or words from 1m to 2m, depending on the sound's intensity and volume. The robot audition program utilizes input from an array of microphones to execute sound source location, separation, and recognition of distinct voices (Shigemi *et al*., 2018). The ASIMO robot comprises 20 central processing units distributed throughout its body (Hirose & Ogawa, 2007). ASIMO can walk in a straight line, navigate in a circular path, execute turns, and do slaloms, allowing it to function in various typical human contexts (Hirose & Ogawa, 2007). ASIMO has a total of 57 DoF, with multiple fingers having 13 degrees, enabling the robot to express itself in sign language (Shigemi *et al*., 2018). It has a neck structure with 3 DoF for nodding and tilting the head (Shigemi *et al.,* 2018).

Figure 2.2: ASIMO Robot (Ghazanfa & Ahmed, 2016)

Robot Haru: Haru is an experimental desktop social robot developed to support research into human-robot interactions from several disciplinary and methodological perspectives (see Figure 2.3). The width of its base is 22cm. The base consists of a robust steel framework upon which the robot rotates (Gomez *et al*., 2018). Haru possesses an addressable LED matrix display, a micro speaker, and an electrical control board (Gomez *et al*., 2018). The LED matrix display is contained within a bespoke structure that precisely conforms to the external shell's curvature (Gomez *et al*., 2018). The LED matrix display is engaged to show a smiling mouth internally (Gomez *et al*., 2018). The electronic control board comprises a central processing unit that manages sensor and actuator functions, display signals, and audio output via the speaker (Gomez *et al*., 2018). Haru possesses two eyes, including LED screens, dynamic rims integrated with addressable LED strips, and an LED matrix mouth (Jelinek *et al.*, 2024). The LED matrix mouth rotates together with the base. Haru can tilt both eyes simultaneously in an upward and downward direction for 60 degrees of displacement, which refines the robot's eye contact posture with a user (Gomez *et al*., 2018). Haru possesses seven DoF, including eye tilt, rotation, inner eye movement, base rotation, and body inclination, enabling the generation of dynamic emotional messages (Jelinek *et al*., 2024). Haru may advance and retreat at an angle of 57 degrees. The forward motion indicates aggression, interest, and curiosity, whereas the reverse motion signifies retreat and fear (Gomez *et al*., 2018).

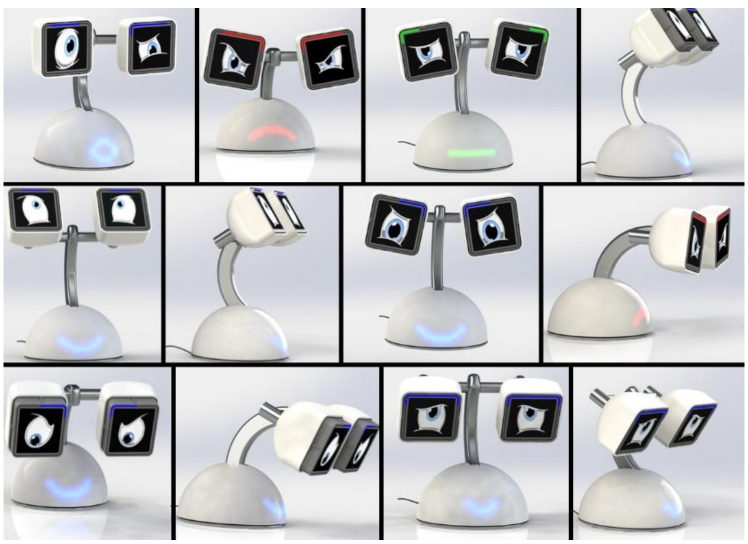

Figure 2.3: Robot Haru in different positions (Ackerman, 2018)

Pepper Robot: Pepper is an autonomous humanoid robot developed by Aldebaran Robotics and launched in 2014 by SoftBank Robotics, following SoftBank's acquisition of Aldebaran Robotics in the same year (Allan & Bartneck, 2022). In 2015, Pepper was exclusively available in Japan; by June 2016, it had expanded to Europe; in November 2016, it entered the US market (Gardecki & Podpora, 2017). Pepper's principal target market and most intuitive use is human interaction (Gardecki & Podpora, 2017). The microcontroller of the Pepper robot operates on a specialized, Linux-based system known as NAOqi (Pandey & Gelin, 2018). It comprises multiple library modules, allowing developers to program the robot's resources (Pandey & Gelin, 2018). Pepper's microcontroller features a central processing unit (CPU) with a speed of 1.91 GHz and 4 GB of memory (Pandey & Gelin, 2018). It features an additional 3GB of flash memory for storing programs (Pandey & Gelin, 2018).

Pepper has 20 DoF from 17 joints in its whole body (Gardecki & Podpora, 2017). Pepper joints utilize electric servo drives equipped with high-speed DC motors, generating power and torque that align with the specifications of a joint (Gardecki & Podpora, 2017). The joints utilize a 12-bit magnetic rotary encoder technology based on the Hall Effect to ascertain the robot's current location (Gardecki & Podpora, 2017). Pepper's fully charged battery lasts 12 hours of operation, contingent upon job intensity (Gardecki & Podpora, 2017). The battery charges during operation; however, the robot's wheels are disabled while charging, rendering it immobile (Gardecki & Podpora, 2017).

Pepper can be programmed using the offline robot programming method. The proprietary software, Choregraphe, for developing its core functions is compatible with Windows, Linux, and macOS operating systems (Gardecki & Podpora, 2017). Choregraphe enables programmers to build Pepper applications using Python, C++, or Java, and to evaluate these applications through simulations (Gardecki & Podpora, 2017).

Pepper is 1.2 meters tall and weighs 28 kg. It features three omnidirectional wheels, enabling Pepper to move freely in all directions. Pepper has multiple sensors to detect objects and individuals in its environment (Hohnloser & Hellstrom, n.d.).

Pepper is equipped with six inertial measurement units (IMUs), each consisting of a three-axis gyroscope with an angular velocity of approximately 500 degrees per second and a three-axis accelerometer (Pandey & Gelin, 2018). Pepper has four microphones on its head to facilitate sound localization (Pandey & Gelin, 2018). The robot features two red-green-blue (RGB) cameras positioned at the forehead and mouth (Pandey & Gelin, 2018).

The resolution is 2,560 × 1,920 at one frame per second or 640 × 480 at 30 frames per second (Pandey & Gelin, 2018). A single 3-D sensor is located posterior to the eyes (Pandey & Gelin, 2018). This 3-D sensor delivers an image resolution of up to 320 × 240 at 20 frames per second (Pandey & Gelin, 2018). There are three tactile sensors: one in the head and one in each hand (Pandey & Gelin, 2018). The robot has three bumper sensors positioned at each wheel location (Pandey & Gelin, 2018).

Furthermore, it possesses a tablet affixed to its chest (Pandey & Gelin, 2018). The Pepper robot features two loudspeakers positioned laterally on the left and right sides of its head, two sonar sensors—one at the front and one at the rear—and two infrared sensors located at the base (Pandey & Gelin, 2018). Figure 2.4 shows the Pepper robot.

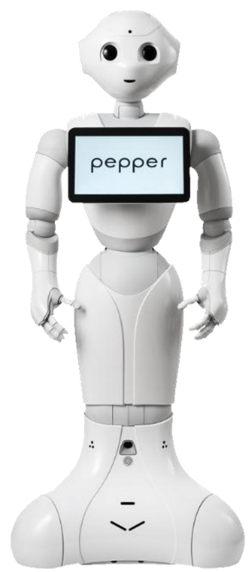

Figure 2.4: Pepper Robot (Guizzo, 2014)

2.1.1.2. Social media platforms

As defined by Carr and Hayes (2015), social media platforms are Internet-based platforms that allow users to engage with broad and targeted audiences intentionally and opportunistically, either asynchronously or in real-time formats. These audiences find that user-generated material and the impression of social engagement benefit the overall experience. According to Carr and Hayes (2015), social media platforms enable users to share information and other content through websites and applications hosted on the Internet. Carr and Hayes (2015) stated that several social media platforms allow users to create online communities for exchanging information and other forms of content. Some shared social media contents include texts, photos, videos, music, etc. Examples of social media platforms include X (Twitter), Facebook, TikTok, Pinterest, Instagram, Snapchat, LinkedIn, YouTube, WhatsApp, WeChat, and Telegram. The following section presents descriptions of some social media platforms for creating and sharing stories.

Facebook: According to Nations (2024), Facebook is a social networking website that enables users to watch short-form videos, post comments, share images, publish links to news or other web content, engage in live chat, and exchange links to other websites. Facebook was founded in February 2004 by Harvard University students Mark Zuckerberg, Chris Hughes, Andrew McCollum, Dustin Moskovitz, and Eduardo Saverin (Kemer, 2021). The Facebook website (www.facebook.com) allows individuals to create accounts (see Figure 2.5). When creating an account, the individual must enter personal information, such as their first name, last name, mobile number, email address, password, date of birth, and gender (Chi, 2019). Users can connect, share photographs, videos, audio recordings, and engage in group chats through Facebook Messenger (Chi, 2024). Facebook enables users to generate digital stories by selecting the plus symbol on mobile platforms or the menu button on desktop platforms, followed by clicking on 'story' (Chi, 2024). Facebook stories are only visible for twenty-four hours (Chi, 2024). After twenty-four hours, the story's content is lost (Chi, 2024). People can also make friends with others through Facebook.

Facebook has become a platform for businesses to advertise their products to potential customers. Users of Facebook should be familiar with specific terms to use the platform effectively. These terms include profile, page, news feed, timeline, post/status, friends, followers, groups, events, and notifications. A profile is a place where an individual's account information is displayed. The information includes the user's name, photo, hometown, workplace, educational history, and other details (Chi, 2024). A Facebook page is a profile for a business, organization, or institution. A Facebook page contains information such as the type of industry, business overview, contact information, business hours, logo, and branding (Chi, 2024). According to Chi (2024), the Facebook feed is the location where all posts that you "like" or "follow" from friends or businesses will be displayed. A timeline records all posts posted or interacted with, particularly by an individual or a company (Chi, 2024). It takes the form of a post and is shown on profiles and pages (Chi, 2024). According to Chi (2024), "post" is used on Facebook to describe something you share on the news feed. The news feed allows you to share various posts with friends, including text, photographs, videos, and location (Chi, 2024). These posts can be shared with your friends. Friends are those to whom you have extended an invitation, and they have accepted it, or individuals who have extended an invitation to you and you have been able to receive it (Chi, 2024). According to Chi (2024), followers have chosen to receive updates from a particular profile or page based on their preferences. When you add new friends, they are automatically followed by you, and you are also followed by them (Chi, 2024). A Facebook group is a community of people who engage with one another based on various themes set by the group's administrator and other users (Chi, 2024). Text messages, images, movies, and other media can be shared among group members (Chi, 2024). Facebook provides notifications to users if a friend interacts with their posts, photographs, videos, or timeline (Chi, 2024).

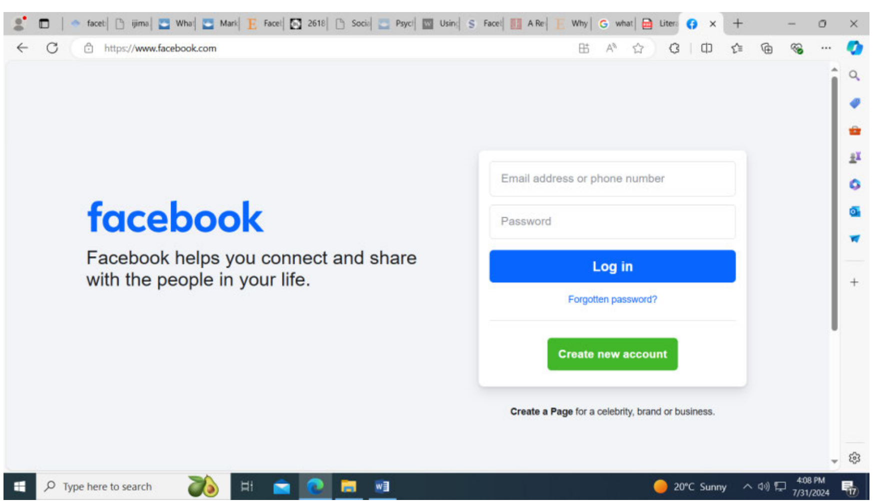

Figure 2.5: Facebook page for creating an account (Facebook, 2025)

TikTok: According to D'Souza (2024), TikTok is a social media platform that enables users to create, share, and watch a wide range of short-form videos online. ByteDance, a Beijing-based company, founded TikTok in 2016 (Miltsov, 2022). TikTok was initially called Douyin for customers within the Chinese domestic market (Miltsov, 2022). As the worldwide version of Douyin, ByteDance introduced TikTok in 2017 (Miltsov, 2022). During the same year, ByteDance merged Musical.ly with TikTok after acquiring the lip-syncing app Musical.ly, which was popular among adolescents at the time (Miltsov, 2022). TikTok is a user-generated content platform (UGC) where users produce the content (videos) rather than the TikTok engineers (Yang & Zilberg, 2020). Users use the TikTok platform to upload, view, and share short 15-second videos. Users can also assemble these 15-second videos sequentially to create a longer video. Users of TikTok can record a video in TikTok for up to 10 minutes, but they can also upload already-created videos of up to 60 minutes in length.

The TikTok platform offers several features, including a user profile, the ability to follow and be followed, explore, and comment on videos (Miltsov, 2022). TikTok is available for download and installation on the Apple App Store, Google Play Store, and Amazon App Store. Watching videos on TikTok without having an account is possible, but creating an account allows users to engage fully with the app (Anderson, 2020). To create an account or sign up for TikTok, users click on the "Sign Up" button. During the sign-up process, users provide their date of birth, phone number, email address, password, and nickname. The platform then verifies the user's information by sending a verification code to the phone number or email address provided. To create a story using the TikTok platform, a user will go into the inbox and click the "Create" button to add images, text, and other elements to make the story. TikTok allows users to edit videos and add sounds from existing TikTok videos before posting. It also allows users to restrict viewing of their videos to the public, friends, and privately by the creator. Content creators can also turn comments from the public on or off. The TikTok platform utilizes a recommendation algorithm to analyze users' previous activities and adjust to changes in user preferences (Miltsov, 2022). This algorithm tracks users' content and recommends similar videos based on their preferences. The videos tracked appear on the "For you" page (Miltsov, 2022). Figure 2.6 shows the "For you" page of the TikTok platform.

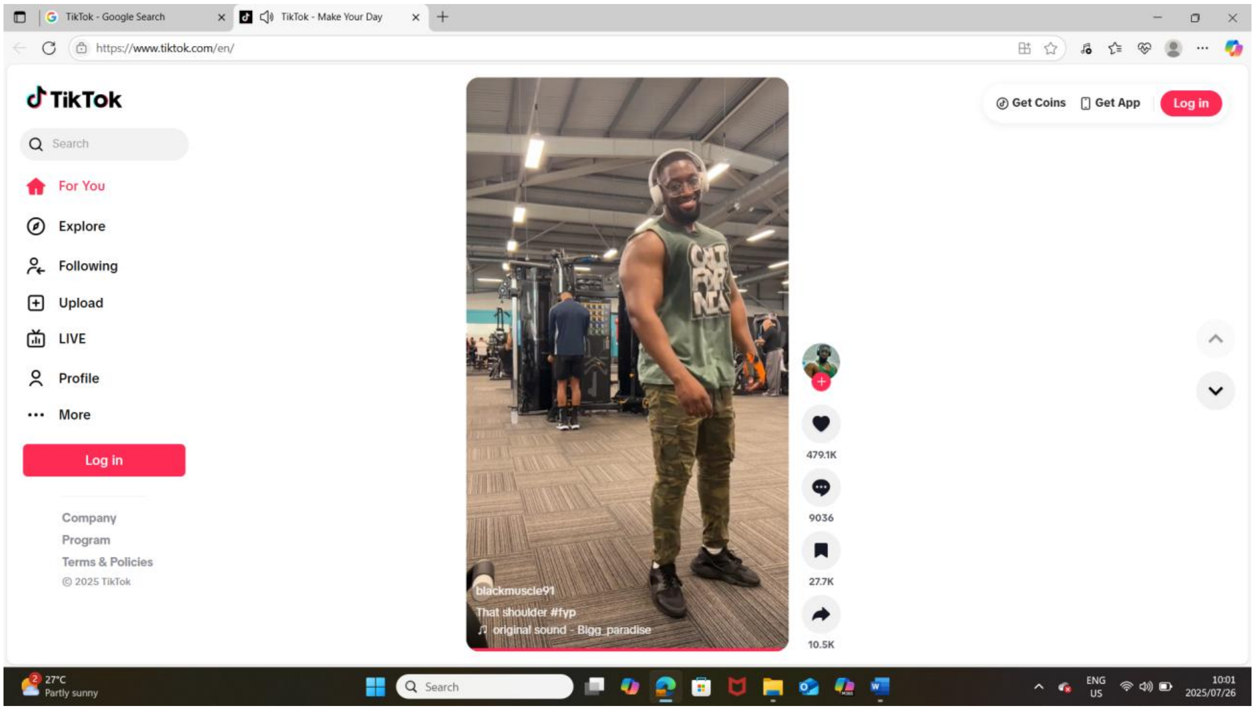

Figure 2.6: TikTok page (TikTok, 2025)

Instagram: According to Musonera (2018), Instagram is a web-based platform that enables users to upload, capture, and share multimedia content, including images and videos. In 2010, Mike Krieger and Kevin Systrom conceived the idea of creating Instagram (Musonera, 2018). Smartphone users can download Instagram from the Google Play Store or Apple App Store. After installing the app, you can create an account on Instagram or log in using a Facebook account. Computer users should log in to www.instagram.com and sign up or create an account. Instagram was initially a photo-sharing app until mid-2013, when it was programmed to include video capturing and sharing (Handayani, 2015).

Instagram has five icons at the bottom of its home page when it is opened on a mobile device, such as a smartphone (see Figure 2.7). The icons are Home, Explore, Post, Reels, and Profile. The home button brings the user back to the starting page after visiting other pages. The post button allows users to share photos, stories, and videos on the Instagram platform. The reel button directs users to the reel page, where they can watch short videos uploaded by other users. The profile button directs the user to the profile page, where they can view their profile information. The profile information includes profile pictures, the number of posts, the number of followers, and the number of users being followed. Users can follow suggested users on the profile page or post photos or videos (Handayani, 2015). Instagram allows users to click on a picture to view it in an enlarged format. In this view, users can like, share, and comment on the post. Connecting Instagram accounts to various social media platforms enables the sharing of images on Instagram with other platforms, such as Facebook and Twitter (Green *et al*., 2018). Instagram allows its users to create short stories to share with others. The story creation page has tools to enable users to add sounds from other posts, photos, and texts. Instagram stories are short videos that display for only 24 hours.

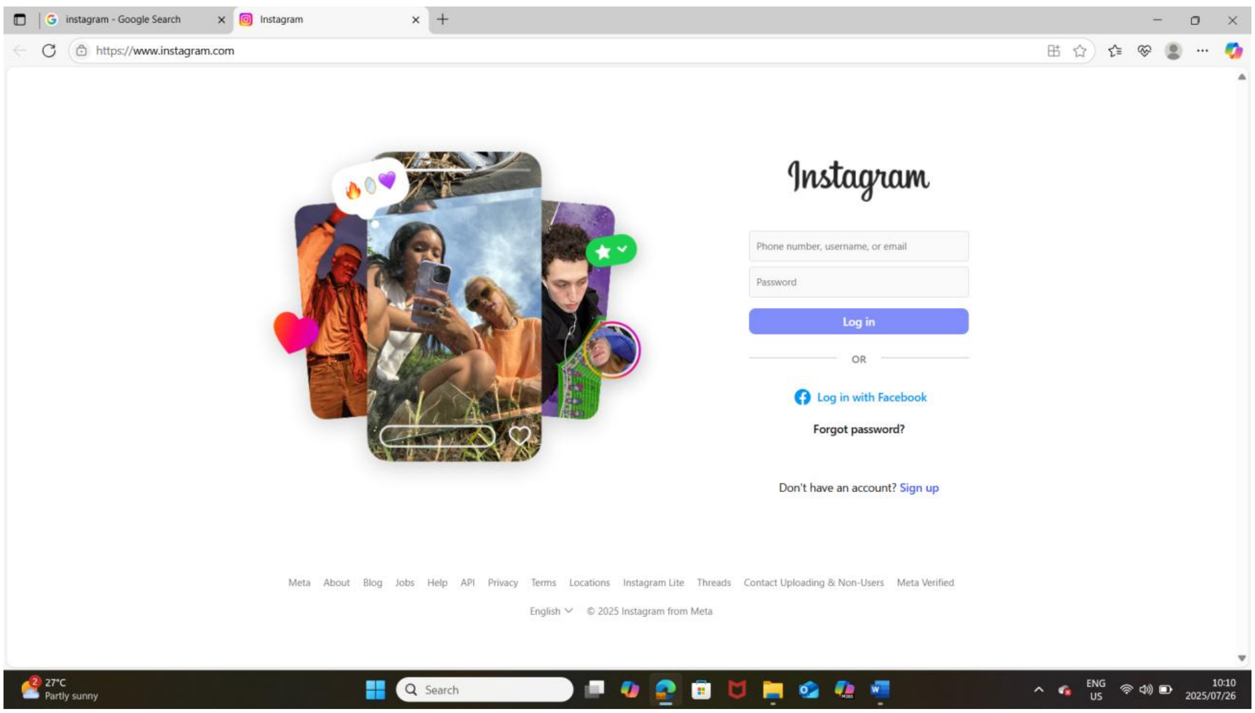

Figure 2.7: Home page of Instagram (Instagram, 2025)

WhatsApp: According to Irfan and Dhimmar (2019), WhatsApp is a free instant messaging service that can be used on various devices, including computers, Android phones, and iPhones. It is a social networking platform that allows users to share text messages, video files, audio files, and other documents (Irfan & Dhimmar, 2019). It also allows its users to make audio and video calls worldwide via the Internet. Information sent through the WhatsApp platform is end-to-end encrypted (Irfan & Dhimmar, 2019). Jan Koum and Brian Acton founded WhatsApp in 2009. It was later acquired by Facebook in

2014 (Irfan & Dhimmar, 2019). WhatsApp allows users to create as many as 100 groups, each with a maximum of 1024 members. The number of messages that users can share on a WhatsApp platform is unlimited (Gon & Rawekar, 2017). WhatsApp can be downloaded and installed on smartphones from the Play Store and App Store. WhatsApp can also be downloaded and installed on a Desktop computer. Users can link the desktop version to a smartphone with a WhatsApp account. The web version connects with your smartphone but works within your browser (Koen, 2021). To use WhatsApp, you must download and install the application on your computer or smartphone (Koen, 2021). After installation, the app will guide you through configuration by asking you to agree to the terms of service, which includes entering your phone number, name, and other details, before finally allowing you to access the interface for sending messages and performing other activities (Koen, 2021). (see figure 2.8)

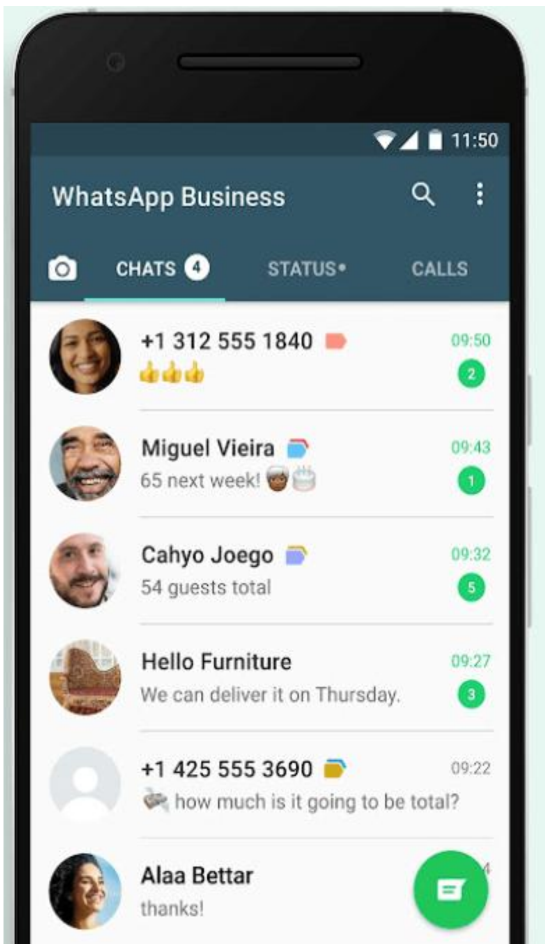

Figure 2.8: WhatsApp interface on a smartphone (WhatsApp Business, 2025)

YouTube: According to Ilyas and Putri's 2020 research, YouTube is a social media network that allows users to watch and share videos. It was founded by Chad, Stevechen, and Jawal Karim in 2005 (Ilyas & Putri, 2020). YouTube allows users to watch videos for free without creating a YouTube account. However, before a user can upload and share a video on the YouTube platform, they must log in to the YouTube platform with a Google account. Users must create a Google or Gmail account and use that account to log onto the YouTube platform. To access the YouTube website, visit www.youtube.com or tap the YouTube icon on your smartphone to open the app. You can upload a profile picture, or YouTube will use the profile picture from your existing Google account. Upon entering the YouTube platform with a Google account, you must click the plus sign in the top left corner of the homepage to initiate the publication of your video.

After uploading the video, YouTube takes you through its configuration before publishing it. The initial phase of the configuration, known as the detail section, enables the addition of a title, video description, and target audience. Regarding the audience, you must decide whether your video is suitable for kids. You must also select whether people under the age of 18 are allowed to watch or not. Additionally, the detail section allows you to choose the language for the video and determine whether to enable comments on your video. There are other settings to configure, which are common in the details section. The second stage of the configuration is the video element stage. Here, the user can add subtitles and captions to the video. The user can also add end-screen visuals and interactive video content. The third stage is the checks stage. Here, you must check copyright issues to avoid any copyright infringement. The last stage is the visibility stage, where you decide whether your video will be visible to the entire public or a private audience.

Additionally, you can decide that only you or a select group of viewers can watch the video. A third option under this stage is unlisted, where anyone with the video link can watch the video. Figure 2.9 displays the image of the YouTube homepage.

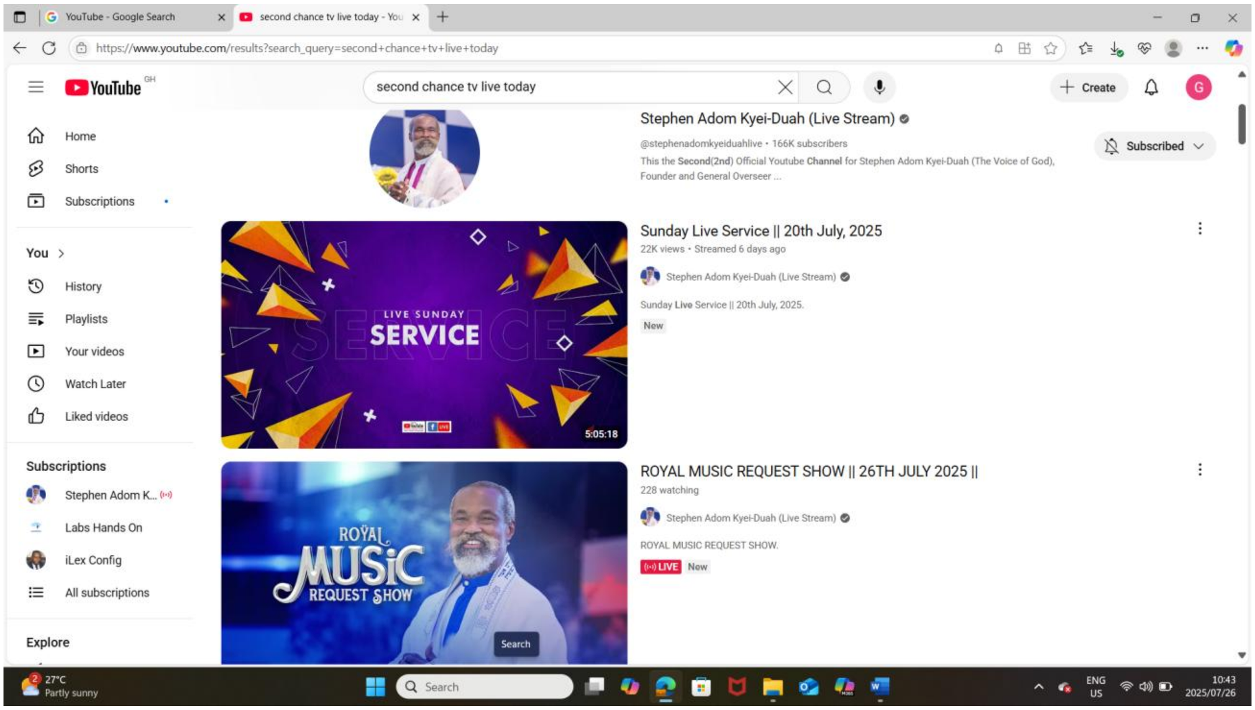

Figure 2.9: Home page of the YouTube platform (YouTube, 2025)

X (Twitter): According to Rigolin (2018), X is a social media platform that enables users to send messages that are up to 280 characters in length. The messages are called tweets, which contain text, video, photos, or links. Twitter is a microblogging platform consisting of blogging and instant messaging services (Hetler, 2024). In 2006, Jack Dorsey, Evan Williams, Biz Stone, and Noah Glass took the initiative to establish the company (Rigolin, 2018). According to Rawat (2024), Elon Musk has owned Twitter since 2022. Twitter has been rebranded as X (Rawat, 2024). To use the X platform, smartphone users must obtain the X software from either the "Play Store" or the "App Store" and then download and install it (Rawat, 2024).

Computer users need to open their browsers and go to https://x.com to open the home page of the X website (see Figure 2.10). After opening the X app or logging onto the home page, one must create an account to access the X platform fully. You must click on the "Create account" button, and X will guide you through the account creation process. During this process, you will be required to provide personal details, such as your name, phone number, and date of birth, to complete the registration. If you already have a Google or Gmail account, you can use that alone to create your account on the X platform.

After users create an account in X, they are referred to as @username on the platform. The username is the username selected during the account creation process or used in the Google account. A user's home page displays some current happenings around the globe, and you can choose to click on any of them to follow. While on your home page, you must also click on the profile icon to enter the profile page. This page shows the counts of your followers and users you are following. On this same page, you can follow others, edit profile information, and add profile pictures. To post tweets, click on the post icon or the plus (+) sign at the side or bottom of the page to open the message box and type your message. Alongside the text, you may incorporate images, videos, emoticons, and other elements into your message before posting. After posting the tweet, all your followers can access it. You can also tweet to select followers by using the @usernames of the individuals at the beginning of the message before posting.

A hashtag creates a category of tweets or discussions by prefixing a word that describes the tweet with a hash (#) symbol. Users can use this hashtag to search for all tweets under this tweet category. For example, users can type #corruption to display all tweets related to corruption discussions that use this hashtag (Kwak *et al*., 2010). The X platform allows users to reply to tweets, repost already posted tweets, and like and share tweets. Reposting, also known as retweeting, enables users to share a tweet with their followers, spreading the information further. To repost a tweet, click on the repost icon under the tweet, giving you two options: repost and quote. The quote allows you to add comments to the tweet before reposting, while the reposting does not allow the addition of comments. According to Kwak *et al*. (2010), X monitors the most frequently used phrases, words, and hashtags and organizes them under "Trends for you" on your homepage.

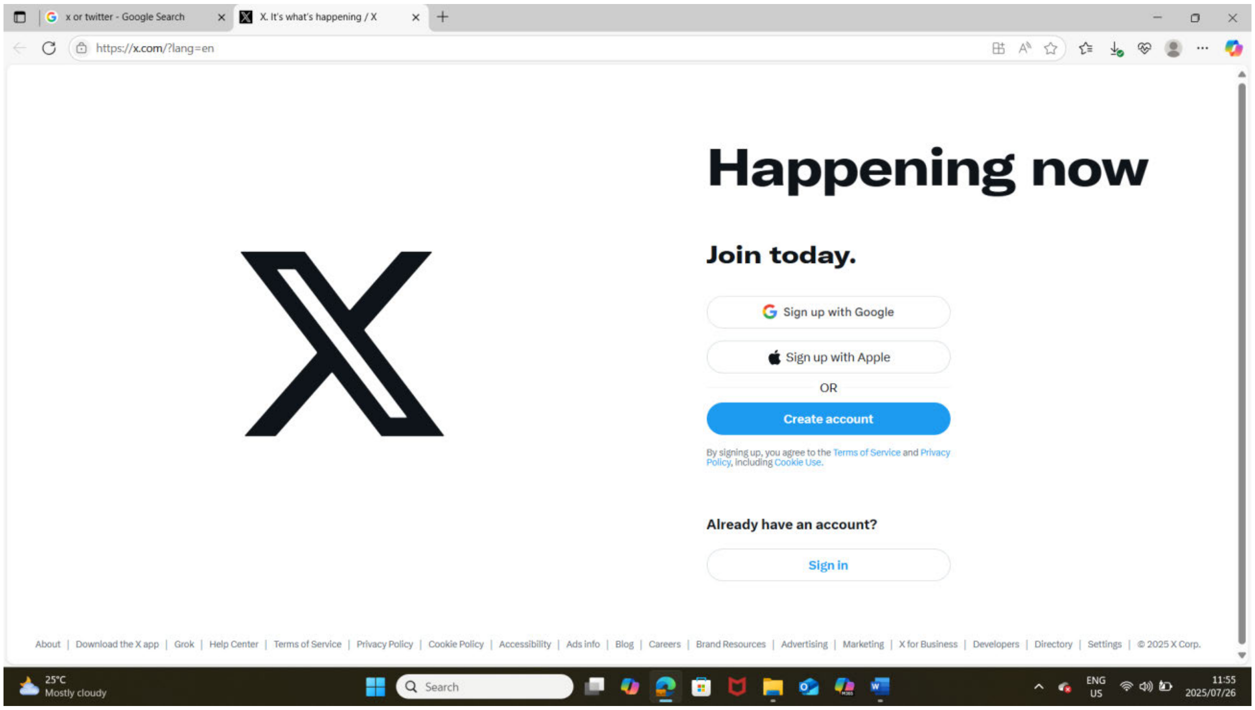

Figure 2.10: Home page of X platform (X, 2025)

Snapchat: This social media platform and messaging app allows users to create and send multimedia messages. Snaps may include a photo or a short video with text captions. These snaps will be available to the recipient for ten seconds (Wilken & Humphreys, 2021). This feature of Snapchat makes it attractive to users who do not want recipients to keep snaps for long. However, a series of snap videos can be combined, lasting about sixty seconds. Snapchat also allows users to create stories and share them with friends or the entire Snapchat community. Such stories can last for 24 hours before they disappear (Villaespesa & Wowkowych, 2020).

Snapchat enables users to transmit text messages or engage in conversation with peers. Snapchat was developed by Bobby Murphy and Evan Spiegel in 2011 (Velten *et al*., 2017). Snapchat is best used on smartphones, though you can install it on a computer. To use the app on a smartphone, go to your app store and search for Snapchat to download and install. Computer users can visit www.snapchat.com to create a Snapchat account (see Figure 2.11). After installing the Snapchat app on your smartphone, click Sign up to open the sign-up page. You will input your first and last names, select a username, enter your email and password or phone number, date of birth, and finally accept the information you have entered. You will be given a verification code via phone or email to enter on Snapchat, which will activate your account.

After creating your account, log in to Snapchat, and you will see a page where your phone's camera is on. You can click on the big circle at the bottom of the screen to take a photo or tap and hold it to take a video. After taking a photo, circular icons will appear on the photo. You can select any of these icons, which are filters and effects, and apply them to your photo. You can also add text captions to your photo. After editing your photo or video, click the "send to" icon to open another page. Here, you can send the snap to a friend in your phone contact, or "My story - friends only" or "My story - public." To chat with a friend, click on the chat icon to open a list of friends from Snapchat or contacts from your phone contact list, and then select the one you want to chat with. Type your message and click send.

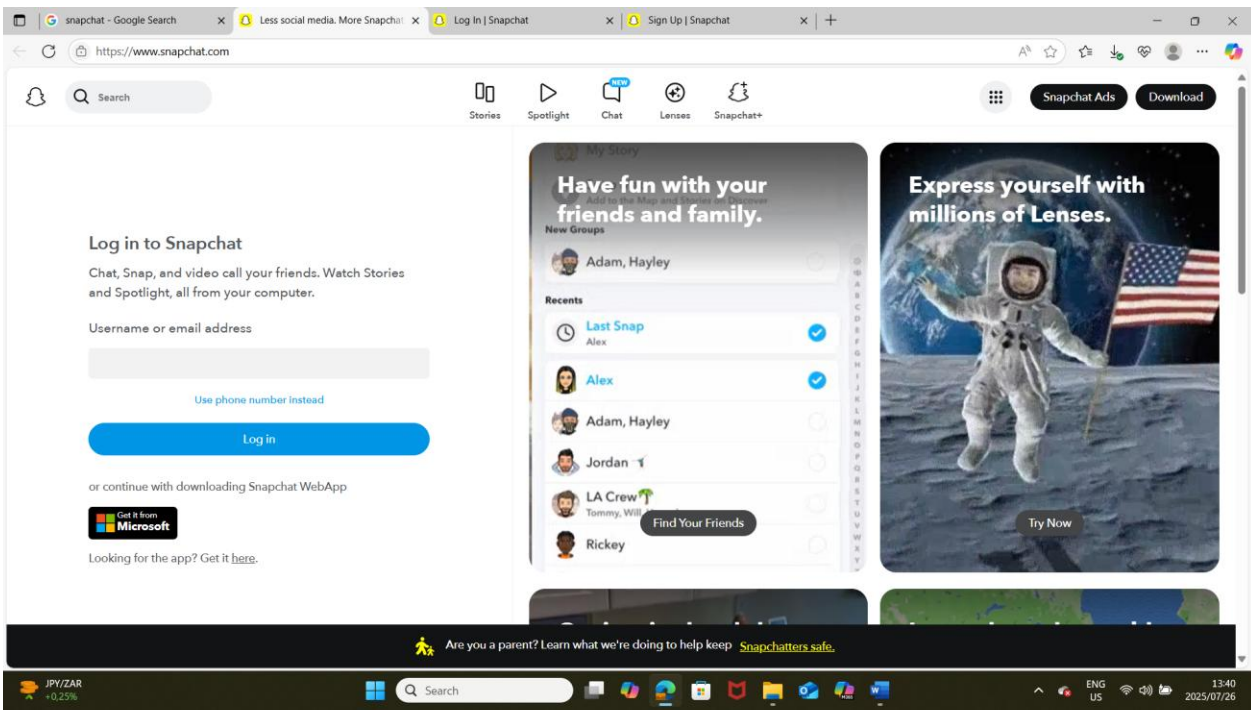

Figure 2.11: Snapchat page on a desktop computer (Log in to Snapchat, 2025)

2.1.1.3. Web-based platforms

Web-based platforms for digital storytelling are websites or online tools that enable users to create and share digital stories online. Examples include Storybird, Pixton, StoryboardThat, Animoto, and Storyjumper websites.

Storybird: Storybird is a platform that enables users to create, read, and share primarily visual digital narratives comprising text and images. It was founded by Mark Ury in 2010 (Arianti, 2018). Storybird offers images for storytelling developers to use in their stories at no cost. Story developers only have to create the text content of their story and add free photos from Storybird (Menezes, 2012). To use Storybird to create and share stories or read stories, you must visit www.storybird.com. (see Figure 2.12). On the Storybird login page, new users must click the sign-up link to create an account.

After clicking sign up, the user must provide a username, date of birth, country, email address, and password. After providing the requested information, the system will deliver an activation email to your email address. At this point, access your inbox, locate the activation email, and click the activation link to complete the account activation process. You can now log into the Storybird platform to create your story. Users with an account on Storybird need to click on login after opening www.storybird.com to log into the Storybird platform. Storybird's homepage features a menu that allows users to write their own stories and read stories created by other users. Storybird enables users to create narratives, including picture books, long-form stories, comics, flash fiction, and poetry. To begin creating your story, click on the Write menu and click on the type of story to create. Select an image for your story cover and continue typing the text. You can also add other photos to your story content. After creating your story, click the Publish button to share it with others, or save it and continue later if the story content is not yet complete.

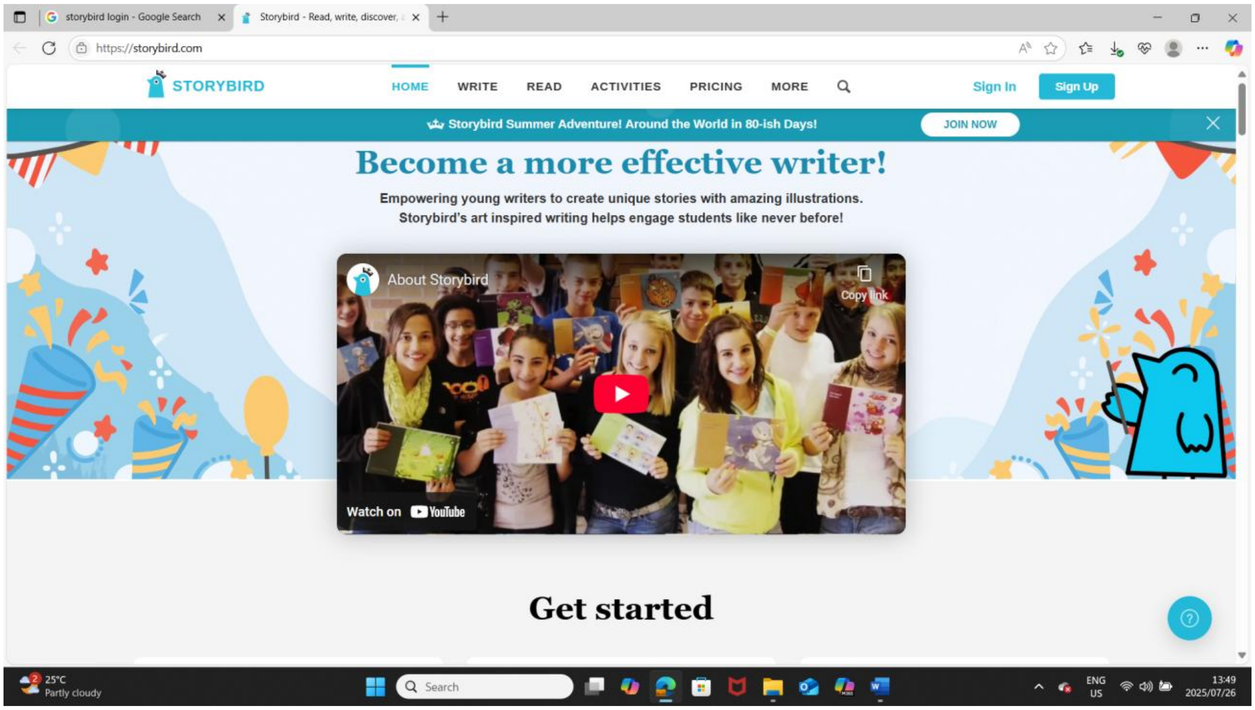

Figure 2.12: Login/Sign up page of Storybird website (Storybird, 2025)

Pixton: *The* Pixton platform is an online tool for creating comic stories, designed for classroom teaching and learning. It allows users to create avatars for their stories. Pixton offers a user-friendly platform that empowers users to be creative with storytelling (Edwards, 2022). Clive Goodinson created Pixton. Users can use Pixton's stories to teach subjects such as English, History, and Social Studies (Edwards, 2022). Pixton allows teachers to create a virtual classroom for their students (Edwards, 2022). Teachers provide students with a sign-in code to access the virtual classroom (Edwards, 2022). Through this virtual classroom, teachers can give comic story assignments to students (Edwards, 2022).

The virtual classroom also enables teachers to view students' work and provide feedback (Isik & Ercan-Demirel, 2022). To use the Pixton platform to create a story, one needs to log in at www.pixton.com (Figure 2.13) and click on the login link if they have already created an account on the platform. If you haven't created an account on the Pixton platform, click on either 'Educator Sign Up' or 'Student Sign Up', depending on whether you are a student or a teacher. To sign up, click the student sign-up link to open a page that asks if your teacher has provided you with a join link. If "yes," the platform will ask you to type the teacher's class code to access the Pixton platform. If you do not have a join link, a page will open asking for your date of birth. After providing the date of birth, you can now log in with either a Google or a Microsoft account. After signing in, you will be on the Pixton platform, where you can begin to create your comic story or characters for your story. To start creating a story, click on the "create my first comic" link to open a page asking you to enter your story's title or what the story is about. The next page will be to select characters and create your story. The Pixton platform features the following menus for creating your story: Background, Characters, Objects, Focus, Words, Faces, and Actions. After creating the story, users can click the "Publish" button to share their work. The Pixton platform automatically saves your story as you create it. Before you publish the story, you will see a preview of it. If you are unsatisfied with the final story, click the edit button to make any necessary changes before publishing it.

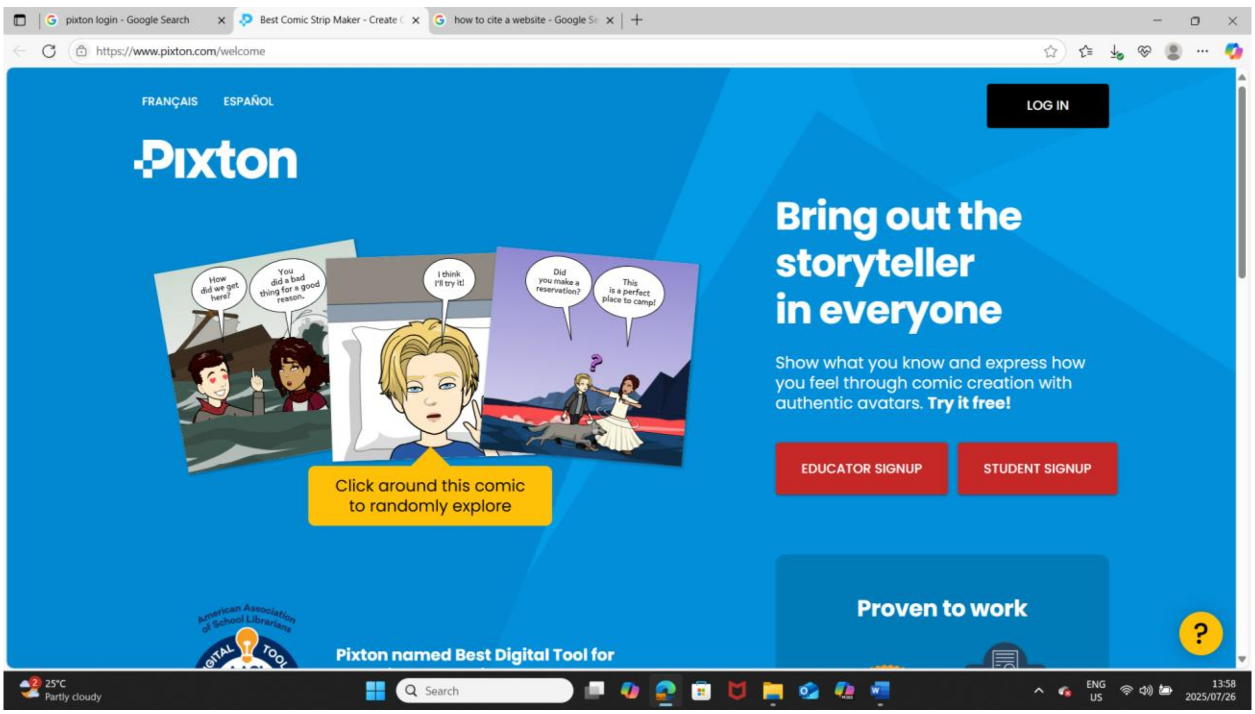

Figure 2.13: Login/Sign up page of Pixton website (Pixton, 2025)

StoryboardThat: StoryboardThat is an online platform that enables users to create storyboards, comics, and graphic organizers with its browser-based storyboard creator (Clever Prototypes, 2024). Aaron Sherman founded StoryboardThat in 2012 (GeneralAssembly, 2024). The StoryboardThat builder enables users to generate storyboards with swift drag-and-drop functionality. The platform quickly brings characters, scenes, themes, and timelines to Life (Clever Prototypes, 2024). StoryboardThat is a versatile, easy-to-use tool that encourages and facilitates digital and visual storytelling (Clever Prototypes, 2024). The StoryboardThat platform allows users to express their opinions through comic strips (Wahjuningsih *et al*., 2020). A comic is a narrative conveyed through illustrations (Clever Prototypes, 2024). It is a series of illustrations, typically arranged horizontally, intended to be interpreted as a narrative or a chronological progression of events (Clever Prototypes, 2024).

To use the StoryboardThat platform to create a story, users should visit www.storyboardthat.com (see Figure 2.14) and then log in. Users with an existing account on the site need to click the login link, input their email address, and provide their password. After providing that information, click 'Log in' to enter your home page. A new user should create an account by clicking the "Register" link, entering their email address, and providing a password. After that, accept the terms and conditions, and click on sign up to enter the welcome page of the StoryboardThat platform. Users can start creating storyboards by clicking on the Create Your Storyboard link, entering the title of the storyboard, and clicking on Continue. The next step is to drag a scene onto the design area. After that, you add characters to the scene and select preset poses for them. Click "Update poses" to add the characters to your scene. StoryboardThat offers users the following choices for storyboard creation: Scenes, Characters, Items, Speech Bubbles, Animations, Shapes, Infographics, Web and Wireframes, Science, and Worksheets (Clever Prototype, 2024).

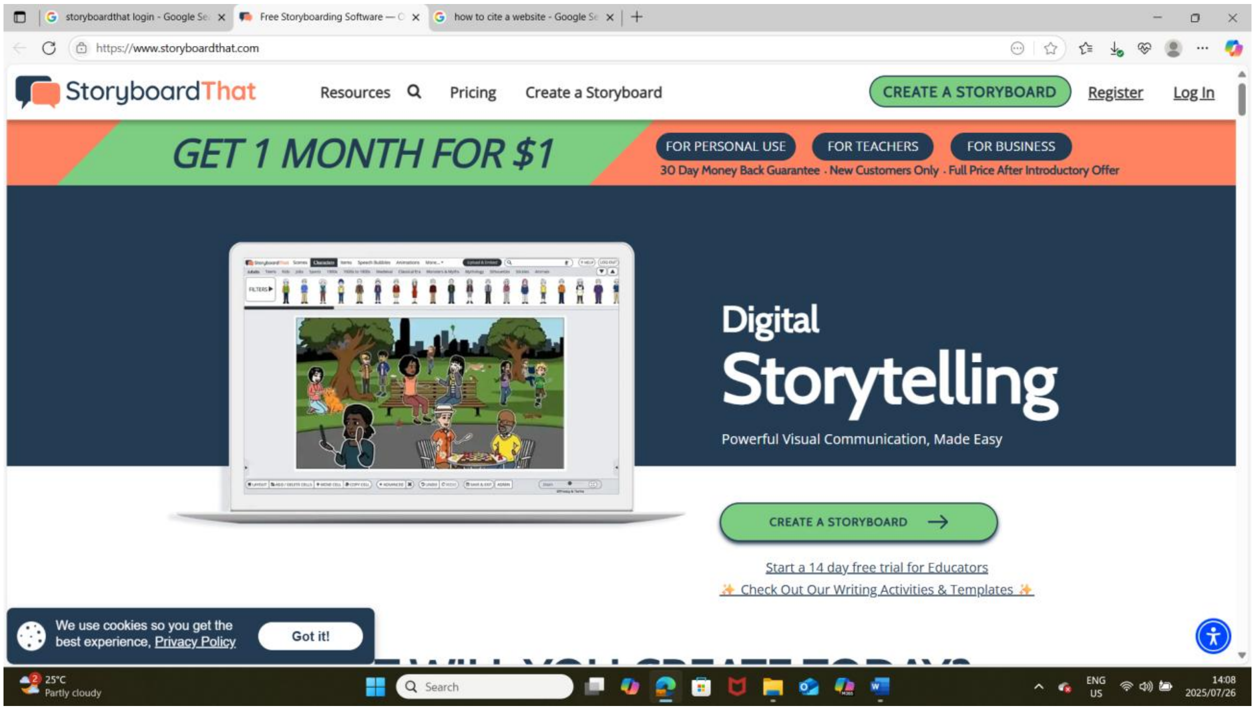

Figure 2.14: Login / Register page of StoryboardThat website (StoryboardThat, 2025)

Animoto: Animoto is a user-friendly tool that enables users to create a brief movie presentation by incorporating photographs, sound, and text (Teachinghistory.org, 2018). Animoto enables users to combine images, sound, and text to create concise narratives through video presentations. The platform allows students to express their thoughts using media technologies, while teachers utilize these tools to connect the curriculum with student involvement or to create digital storytelling projects. (Teachinghistory.org, 2018). Animoto was established in August 2006 by Jason Hsiao, Brad Jefferson, Stevie Clifton, and Tom Clifton (Wikipedia, 2024). Redbrick acquired Animoto in August 2023 (Crunchbase, 2024). Animoto allows students and teachers to create online slideshows with music and text. To use the Animoto platform to create a storytelling video or presentation, users need to log onto www.animoto.com (see Figure 2.15). Users with accounts on the Animoto platform must select the login link, enter their email address and password, and click "Login" to access their workspace. New users must register or establish an account by clicking the free sign-up link.

Upon selecting the free sign-up option, users must provide their email address and password, then click Create Account to finalize the registration process. The first time you log into the platform, it will ask what you will use Animoto for. Business, personal use, education, pro photography, and others are options. After selecting two other options, you will be in the workspace where you can start creating your projects. When a user clicks "Create a video link," the platform prompts the user to choose one of the following options: select a template, start from scratch, or create a slideshow. The user can then proceed to complete the project.

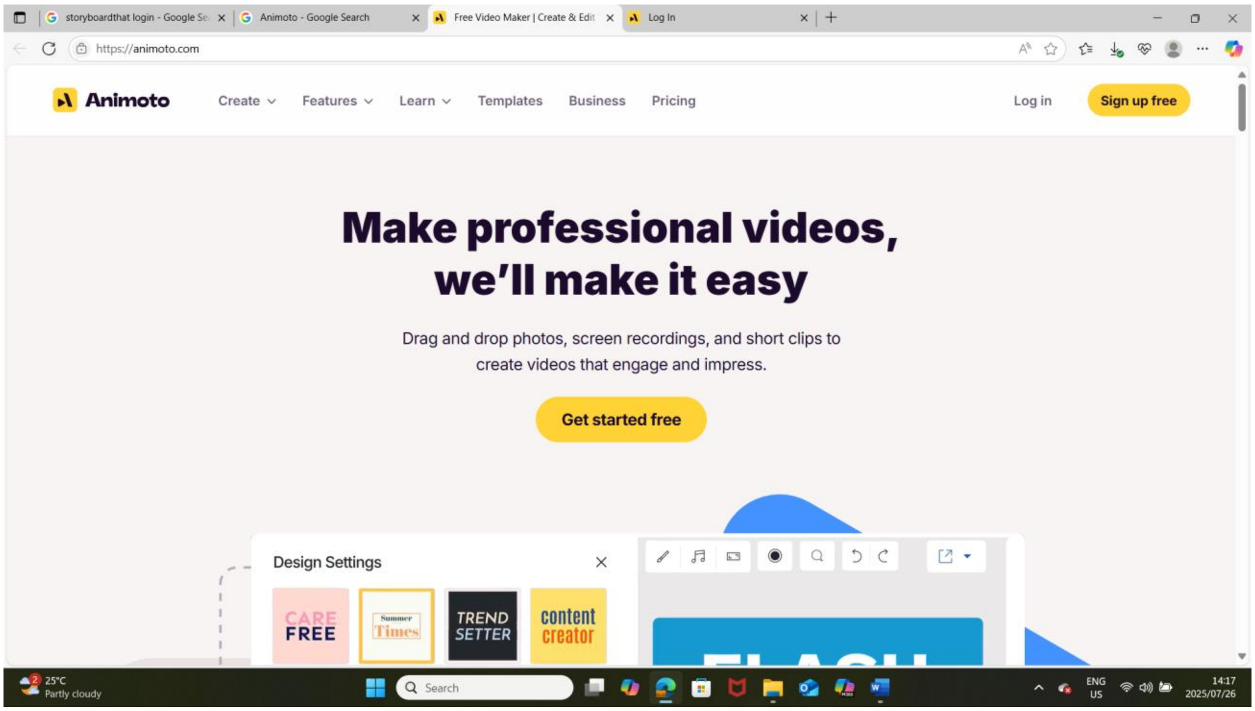

Figure 2.15: Log in and Sign up page of the Animoto website (Animoto, 2025)

Storyjumper: Storyjumper is an online platform for creating storybooks (Trust, 2022). It is a Web 2.0 digital storytelling application that enables users to construct their storybooks (Kumaran *et al*., 2017). Storyjumper was founded by John Yen and Peter Weck in 2009 (Crunchbase, 2024). The Storyjumper platform enables users to create cover pages, incorporate text, and upload illustrations or photographs to enhance their narrative. Users can publish their stories to share with other users. Educators can utilize Storyjumper to establish digital classrooms, foster student collaboration, and provide immediate assessment and feedback on student assignments (Trust, 2022). To use the Storyjumper platform to develop storybooks, users must visit www.storyjumper.com (see Figure 2.16).

Users with existing accounts must click on 'Login', enter their username and password, and then click 'Login' again to access the site. Users new to the platform must create an account by signing up. The platform will then prompt the user to select a username, create a password, and enter their date of birth and email address. Click on Sign Up after providing the requested information. The platform will welcome new users with an overview of the types of stories they can produce with Storyjumper. Click on next, and the wizard will ask a few questions before finally getting access to the Storyjumper platform. On the platform, users can start creating their storybooks. Storyjumper offers video instructions on utilizing the platform for storybook creation. Users can watch such videos before starting their project.

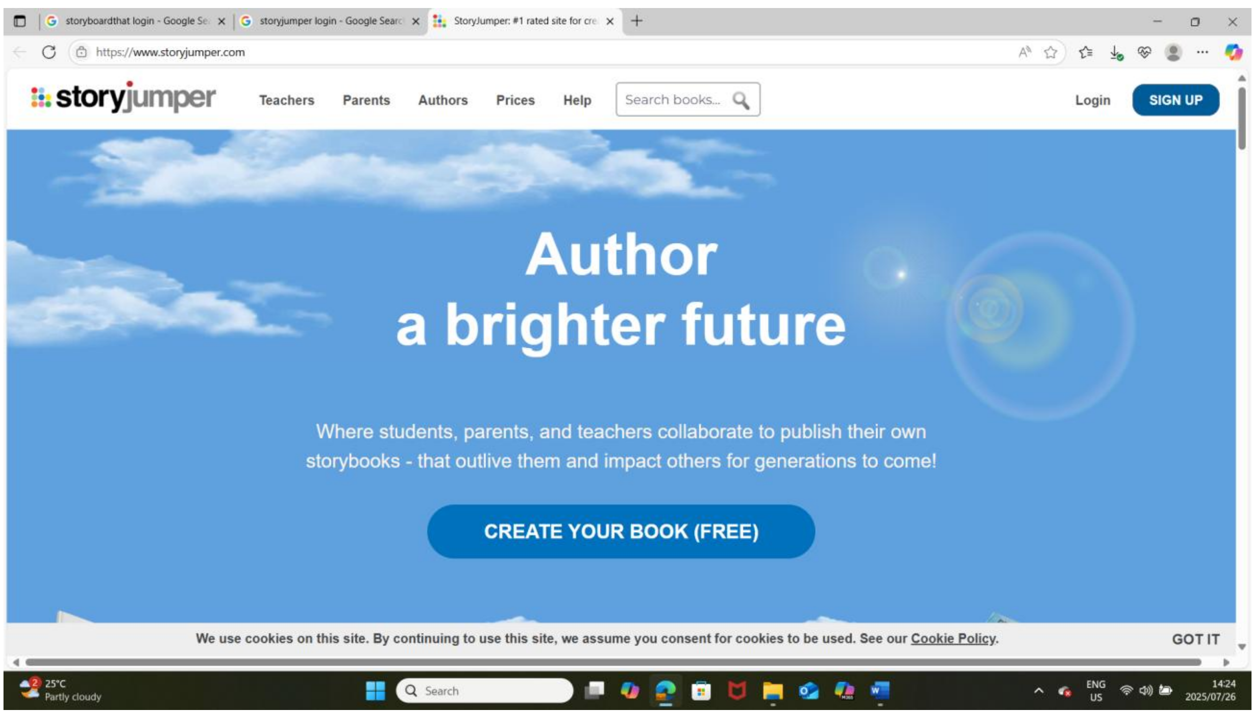

Figure 2.16: Log in and Sign-up page of Storyjumper website (Storyjumper, 2025)

2.1.1.4. Computer-based and mobile device software platforms

Computer-based and mobile device software platforms for digital storytelling are software or applications installed on computers and mobile devices, such as smartphones, that enable the creation of digital stories. Examples include Plotagon, Comic Life, and Wattpad.

Plotagon: Plotagon is a video production tool that includes an intuitive script editor, enabling users to narrate stories using personalized characters, actions, emotions, scientific elements, conversations, music, sound effects, and narratives (Matloob Haghanikar, 2019). Christopher Kingdon created the Plotagon application in 2010, and it was made available to the public in August 2013 (Gurvitch & Lund, 2014). The Plotagon application enables users to select scenes and characters, position characters within those scenes, assign various emotions to the characters, generate dialogue among them, and incorporate sound effects and music (Matloob Haghanikar, 2019). Plotagon is an easy content creation program and storytelling tool for producing short and lengthy films (Guzman Gamez & Moreno Vuellar, 2019). It is used in the classroom to enable students to create animated videos (Guzman Gamez & Moreno Vuellar, 2019). Users can install the Plotagon Studio application on both smartphones and computers. Smartphone users can download the app from the Google Play Store and App Store. However, computer users can download and install the app from www.plotagon.com. After installing Plotagon Studio, open it, and it will prompt you to sign in with your email address and password (see Figure 2.17). Users new to the platform must create an account by signing up. The app will request your full name, email address, and password. Upon receiving the needed information from the user, the platform transmits a verification code to the provided email address. Open the email and enter the code into the text box provided to complete the account creation process. You can now open the Plotagon studio with an email and password. To begin creating your video, click the "Create video" link.

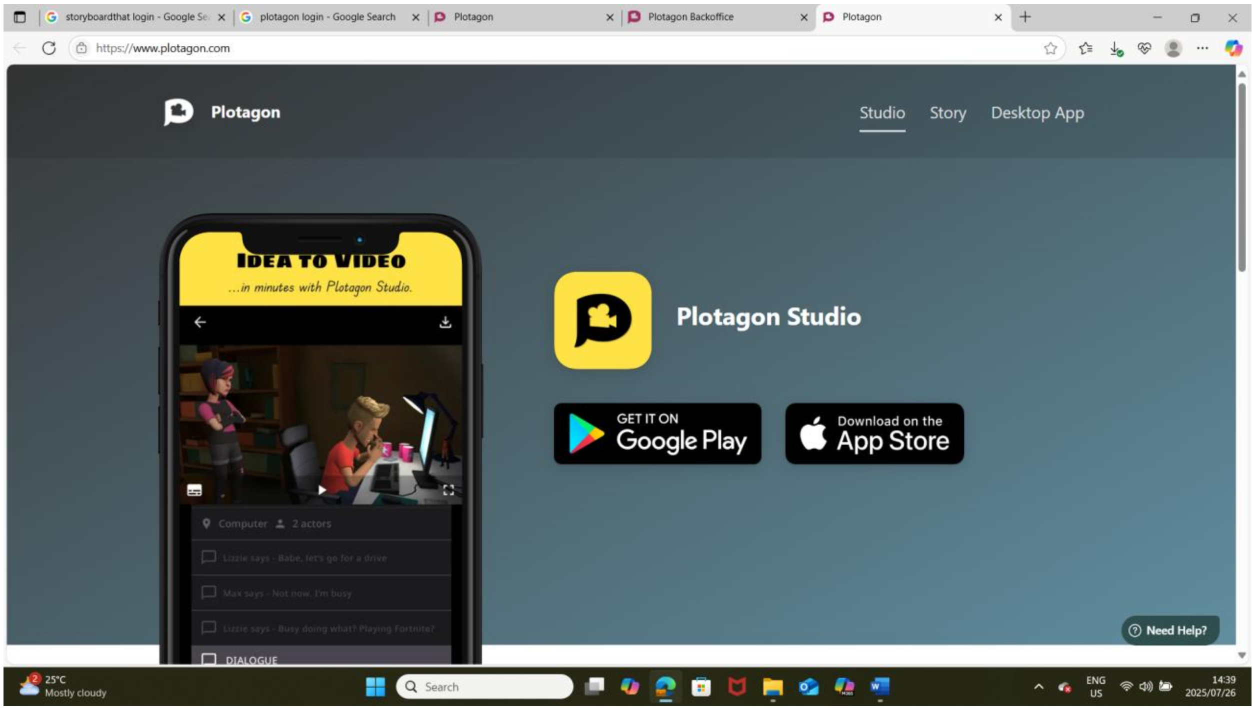

Figure 2.17: Interface of the Plotagon application (Plotagon, 2025)

Comic Life: Comic Life is an application for creating comic books and other graphic documents. A company called Plasq created the Comic Life application (Plasq, 2024). The Comic Life application enables users to create posters and comics that are rich in media. Comic Life also enables users to create life stories and educational materials for teaching and learning purposes. Comic Life makes creating digital comics easy. It enables users to create high-quality comics for online posting, video production, and printing hard-copy documents. The application allows users to develop holiday snaps and tell a story. Smartphone users can download and install it from the Google Play Store or App Store. Computer users can log onto www.plasq.com/download/comic-life-desktop/ to download and install the software. After installing the application, users need to register or use the app temporarily for 30 days. Users must purchase a serial number before registering for the Comic Life application. The Comic Life software offers comic and story script templates, enabling users to create comics and other graphic documents. Apart from the templates, users can use blank scripts and comics to start from scratch (see Figure 2.18).

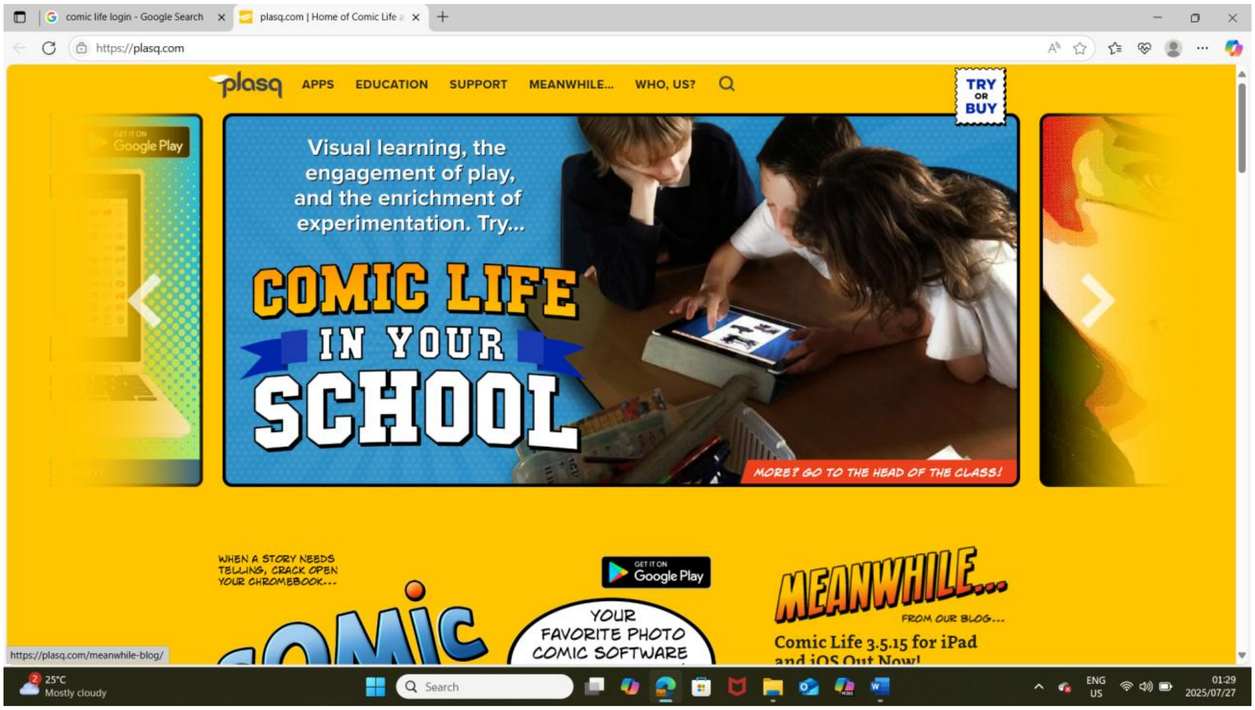

Figure 2.18: User interface of Comic Life application (Plasq, 2025).

Wattpad: Wattpad is a narrative platform that enables users to compose and share their stories while reading works from other authors (Wattpad, 2024). Wattpad dismantles obstacles between readers and authors. It prompts users to write and disseminate narratives across various genres, including teen fiction, poetry, action, adventure, and others (Internetmatters.org, 2024). Allen Lau and Ivan Yuen are credited with creating Wattpad in 2006 (Wattpad, 2024). Wattpad was purchased by Naver in 2021 (Wattpad, 2024). Naver is a South Korean Internet conglomerate that is also home to WEBTOON, a leading global digital comics platform. Wattpad provides various tools for categorizing stories and other types of content, enabling users to avoid inappropriate material or locate specific topics for reading and writing (Internetmatters.org, 2024). Wattpad allows users to categorize their narratives with hashtags on social media (Internetmatters.org, 2024). Users can subsequently search these categories to locate the specific articles and genres of content they wish to read (Internetmatters.org, 2024).

Smartphone users can acquire and install the Wattpad application from any app store, including the Play Store and Apple App Store. Computer users should log onto www.wattpad.com (see Figure 2.19). Users who have created accounts should click "Log in," enter their email address, or log in with a Google or Facebook account. New Wattpad users must establish an account by selecting the sign-up link. Click on the "Sign-up with email" link and provide your email address, username, date of birth, a pronoun to be assigned, and a password. Upon submitting the information, you must consent to Wattpad's Terms of Service and Privacy Policy. Click 'sign up,' and the platform will send a verification link to the email address you provided. Access your email and choose the link to activate your account. The Wattpad platform will greet users with a variety of stories to choose from and read upon logging in. Users can then click on the write link to start creating their stories.

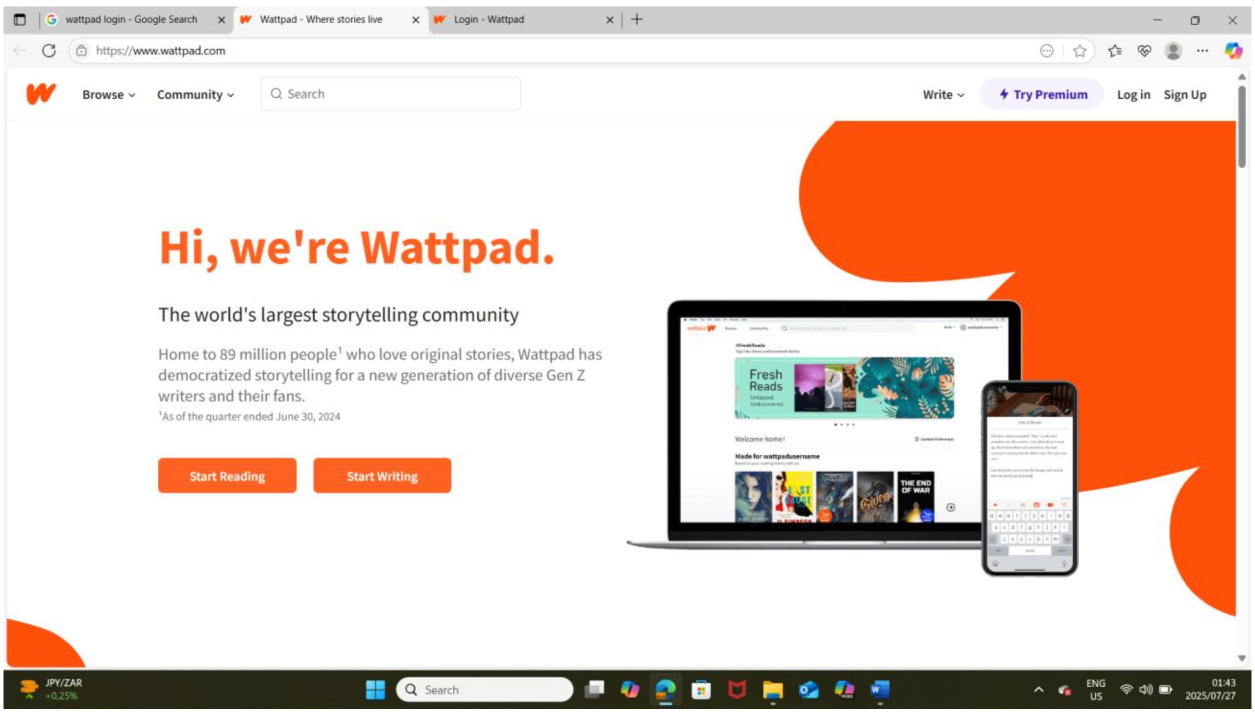

Figure 2.19: Log in and sign-up page for Wattpad (Wattpad, 2025)

2.2. Digital storytelling conceptual models

A conceptual model provides a schematic view of a system's organization and functionality (Johnson & Henderson, 2002). It serves as an intermediary artefact for system development. Conceptual models are schematic representations of a system, theory, or phenomenon of origin, constituting a model (Thalheim, 2012).

The digital storytelling conceptual model is an abstract framework for creating and disseminating digital narratives. It also includes a diagram featuring texts or a list of terms that delineate the elements of compelling digital narratives. The words or text on the diagram are referred to as the elements of the model. The digital storytelling conceptual model outlines the key steps in creating compelling digital stories. These models guide users in developing and sharing good and enjoyable digital stories.

Several pioneers in the field of digital storytelling have proposed conceptual models for digital storytelling developers. Many of these models have elements that inform developers about which characteristics make stories enjoyable and transport audiences into the stories. Most of these models' elements are not relevant to the development of robot storytelling. Table 2.1 presents the leading experts who have developed digital storytelling conceptual models, the key elements from these models, the implications of these elements, and the limitations of the models in the context of robot-based storytelling development. The following are discussions of the experts who have proposed digital storytelling conceptual models and the elements in their models.

Joe Lambert proposed a seven-element conceptual model for digital storytelling. The elements in Lambert's model are “a point of view, a dramatic question, emotional content, the gift of your voice, the power of the soundtrack, economy, and pacing” (Kogila *et al*., 2020). Lambert's model recommends that a story should contain a statement that creates a question to engage viewers and make them anticipate an answer to the question in the story flow. The model also recommends that the story evokes a strong emotional feeling in the audience and has an enjoyable soundtrack in the background. Furthermore, a compelling narrative incorporates minimal media elements, including text, photos, and video, while maintaining a storytelling rhythm and pace that is neither slow nor rapid, allowing the audience to comprehend the narrative.

Porter is another innovator in the realm of digital storytelling. Porter proposed a six-element conceptual model for digital storytelling. The elements are “living in your story, unfolding lessons learning, developing creative tension, economizing the story told, showing not telling, and developing craftsmanship” (Kogila *et al*., 2020). Porter's model recommends that a story should teach a lesson and, from the beginning, put viewers in a state that makes them anticipate certain events in the story flow. The model also suggests that the narrative incorporates fewer media elements to communicate its meaning effectively. Lastly, the story should involve images to minimize narration.

Robin proposed a ten-element conceptual model for digital storytelling developers. “The elements are the overall purpose of the story, the narrator's point of view, a dramatic question, the quality of the images, video & other multimedia elements, the use of a meaningful audio soundtrack, the choice of content, the pacing of the narrative, exemplary grammar and language usage, the economy of the story detail, and clarity of voice” (Kuan *et al*., 2011). Robin's model recommends that a story should have a primary objective. The story should also include a statement that creates a question in the audience's minds, making them attentive and expecting to see an answer to the question within the story flow. The model also recommends that developers use fewer and higher-quality multimedia elements, along with a soundtrack, to create the story. Additionally, the story's rhythm and pace must be neither too slow nor too fast for audiences to follow the narrative. Lastly, the storyteller's voice must be clear, and the language must be free of grammatical errors to convey the story effectively.

Ohler, an additional innovator in the domain of digital narrative, proposed an eight-element model with the following elements: “point of view, emotional engagement, tone, spoken narrative, soundtrack music, the role of video and performance, creativity and originality, time, story length, and economy” (Kogila *et al*., 2020). Ohler's model recommends that a story has a primary objective and evokes a strong emotional feeling in the audience. The storyteller must have a clear voice and display attitudes to indicate amusement, anger, or sorrow. Stories should incorporate images and other multimedia elements to minimize the amount of narration. Developers should also use an enjoyable soundtrack to connect audiences to the story. Lastly, the model recommends that developers use fewer multimedia elements to create the story, thereby reducing costs, and the story should also be concise.

Selpeter proposed a six-element conceptual model containing the following elements: “personal, beginning with the story script, concise, using readily available source materials, including universal story elements, and involving collaboration” (Kuan *et al*., 2011). Selpeter's model recommends that the storyteller personalize the story to make the audience feel more emotionally involved. Additionally, the story creation process should begin with a script. The story should be concise and crafted from readily available resources. The story should encompass all the essential elements, including plot, characters, and point of view. Finally, the creation of the story can be done jointly with others.

Another conceptual model, “Paul and Fiebich proposed, has five elements: media, action, relationship, context, and communication” (Kuan *et al.,* 2011). This concept advocates for storytellers to incorporate media aspects to craft narratives that engage viewers and promote interactivity.

Schafer proposed a model containing twelve elements. The elements are “concreteness, user contribution, coherence, continuity, structure, cognitive effort, virtuality, spatiality, control, interactivity, collaboration, and immersion” (Kuan *et al*., 2011). Schafer's model recommends that story creation software should have predefined objects and characters. It also suggests that the story should be logical, consistent, and flow smoothly from the beginning to the end without interruption. Storytelling developers should understand the software used to create the story and have control over it. The story should be engaging and incorporate the essential elements of a narrative.

Nicholas also proposed a seven-element conceptual model to digital storytelling developers. The elements of this model are “audience, purpose, content, voice, technology, connections, and economy” (Harun & Shiratuddin, 2009). This model recommends that a story has a primary objective. The developers must also consider the target audience when creating the story. The story content must also match the story's theme. The model also suggests that the storyteller has a clear voice to convey the story's meaning and utilizes the appropriate technology to bring it to life. Lastly, the story should have fewer media elements to reduce costs.

Tenh *et al*. (2012) proposed a fifteen-element digital storytelling conceptual model for storytelling developers. The elements of the model are “perspective, intention, personal, dramatic question, engagement, articulation, soundtrack, minimal, tempo, story map, expression, significant content, collaboration, communication, and user contribution”

(Tenh *et al*., 2012). This model recommends that a story be objective and evoke a strong emotional feeling in the audience. A story should have an enjoyable soundtrack to engage viewers. The storyteller must personalize the story to make the audience feel more emotionally involved. The storyteller's voice must be clear to convey the story's meaning.

Additionally, developers must select content that aligns with the theme of the story. The story must also be interactive, neither too slow nor too fast. The story must have a dramatic question to engage viewers and make them attentive and anticipate certain events to happen in the story.

Chang *et al.* (2023) proposed a four-element conceptual model for creating robot-assisted digital storytelling. This conceptual model guides developers in creating and sharing digital stories. The model was experimented with at a teaching hospital, using robot storytelling to teach a diabetes lesson plan design. The model contains the following elements: "brainstorming, selection, forming, and evaluation & reflection" (Chang *et al.,* 2023). This model recommends that storytelling developers discuss and determine the story content and then program the robot accordingly. The story presentation follows programming. Storytellers should evaluate the storytelling activities after the presentation and finally reflect on the evaluation outcomes. Table 2.1 presents the elements of the conceptual models, imports of these elements, and limitations related to robot-assisted digital storytelling.

Table 2.1: Digital storytelling model elements and their limitations in robot storytelling

Expert (year) / (Primary/secondary source)	Model's elements / Source	Import of the elements	Limitations
Porter (Kogila *et al*., 2020)	▪ "Living in your story ▪ Unfolding lessons learning	• The storyteller should be engrossed in the story	▪ The model is silent on the requirements analysis of a story.

	▪ Developing creative tension ▪ Economizing the story told ▪ Showing not telling ▪ Developing craftsmanship" (Kogila *et al.*, 2020)	• The story should teach a lesson • The story should put viewers in a state that makes them anticipate certain events and hold their attention. • The story should be made with fewer media elements to convey the meaning. • The story should involve images to reduce the amount of talking • The storyteller should display competence and produce a quality story	▪ The model did not include hardware, software, or multimedia elements. ▪ The model is silent on the evaluation of storytelling.
Lambert (Kogila *et al.*, 2020)	▪ "A point of view ▪ A dramatic question ▪ Emotional content ▪ The gift of your voice	▪ The first point mentions the story's main point and the teller's perspective. ▪ A dramatic question is	▪ The model is silent on the requirements analysis of a story.

	▪ The power of the soundtrack ▪ Economy ▪ Pacing" (Kogila *et al.*, 2020)	a statement at the beginning of the story that creates a question in the viewer's mind. ▪ The story should evoke a strong emotional feeling in the audience ▪ The storyteller must use a clear voice to convey the meaning of the story ▪ The soundtrack, which is the sound played in the background of a story, should be enjoyable to connect the viewers to the story ▪ The story should be made with fewer media elements to convey the meaning.	▪ The model did not include hardware, software, or multimedia elements. ▪ The model is silent on the evaluation of storytelling.

		▪ The story's rhythm and pace must be neither too slow nor too fast, but balanced, for viewers to understand the narrative.	
Robin (Kuan *et al.,* 2011)	▪ "The overall purpose of the story ▪ The narrator's point of view ▪ A dramatic question or questions ▪ Quality of the images, video & other multimedia elements ▪ Use of a meaningful audio soundtrack ▪ The choice of content ▪ The pacing of the narrative	▪ The main objective of the story ▪ The storyteller's position on the story ▪ A dramatic question is a statement at the beginning of the story that creates a question in the viewer's mind. ▪ The storyteller must ensure that the story includes high-quality multimedia elements. ▪ The soundtrack should be	▪ The model is silent on the evaluation of storytelling

	▪ Good grammar and language usage ▪ The economy of the story details ▪ Clarity of voice." (Kuan *et al*., 2011)	enjoyable to connect the viewers to the story ▪ The right multimedia content ought to be selected to match the theme of the story ▪ The rhythm and speed of the story must neither be too slow nor too fast, but must be balanced for viewers to understand the story ▪ The storyteller's language must be free of grammatical errors and meaningful to the audience ▪ The story should be made with fewer media elements to	

		convey the meaning. ▪ The storyteller's voice must be clear to convey the meaning of the story	
Ohler (Kogila *et al*., 2020)	▪ “Point of view ▪ Emotional engagement ▪ Tone ▪ Spoken narrative ▪ Soundtrack music ▪ Role of video and performance ▪ Creativity and originality ▪ Time, story length, and economy” (Kogila *et al.,* 2020)	▪ The first point mentions the story's main point and the teller's perspective. ▪ The story should evoke a strong emotional feeling in the audience ▪ The tone displays the storyteller's attitude to indicate amusement, anger, or sorrow ▪ The narrator's voice must be clear to convey the meaning of the story ▪ The soundtrack should be enjoyable to connect the	▪ The model is silent on the requirements analysis of a story. ▪ The model is silent on the evaluation of storytelling.

		viewers to the story ▪ The story creation should involve video and other multimedia elements to reduce the amount of narration ▪ Use your skills and resources to craft a story that will attract viewers' attention ▪ The storyteller should create the story with fewer media elements to make it concise and ensure it conveys the intended meaning.	
Salpeter (Kuan *et al*., 2011)	▪ "Personal ▪ Begin with the story script ▪ Concise ▪ Use readily available source materials	▪ The storyteller should personalize the story to make the audience feel more emotionally involved.	▪ The model did not include hardware, software, or multimedia elements.

	▪ Include universal story elements ▪ Involve collaboration" (Kuan *et al*., 2011)	▪ Prepare the written document of the story ▪ The story should not be too long to create boredom ▪ The story should use readily available resources ▪ The story should have essential elements, including plot, character, setting, conflict, and point of view. ▪ The story developers should involve others to create the story	▪ The model is silent on the evaluation of storytelling.
Paul and Fiebich (Kuan *et al*., 2011)	▪ "Media ▪ Action ▪ Relationship ▪ Context ▪ Communication" (Kuan *et al*., 2011)	▪ The story should use media elements ▪ The story should have something to show what is happening at any moment	▪ The model is silent on the requirements analysis of a story. ▪ The model is silent on the

		▪ The story should connect the audience to the story or transport them into the story ▪ The storyteller should describe the story's context ▪ The story should be interactive	evaluation of storytelling.
Schafer (Kuan *et al.*, 2011)	▪ “Concreteness ▪ User contributions ▪ Coherence ▪ Continuity ▪ Structure ▪ Cognitive effort ▪ Virtuality ▪ Spatiality ▪ Control ▪ Interactivity ▪ Collaboration ▪ Immersion” (Kuan *et al.*, 2011)	▪ The story should have objects and characters pre-defined in the software ▪ Users should be able to contribute to the storyline ▪ The story should be logical and consistent ▪ The story should flow from the beginning to the end without a break ▪ The narrative should have the essential	▪ No hardware, and multimedia elements preparation for storytelling. ▪ The model is silent on the evaluation of storytelling.

		elements of a story ▪ Users need to understand the story-creation software ▪ The integration of a virtual environment in the story creation ▪ How far objects in space, space itself, and navigation are of relevance in the development of the story ▪ Users should have control over the flow of events ▪ The storytellers should make their stories interactive ▪ The story developers should involve others to create the story ▪ The story should absorb the	

		storyteller into the story	
Nicholas (Harun & Shiratuddin, 2009)	▪ "Audience ▪ Purpose ▪ Content ▪ Voice ▪ Technology ▪ Connections ▪ Economy" (Harun & Shiratuddin, 2009)	▪ The story should target particular viewers ▪ The story should have a primary objective ▪ Storytellers should select content to match the theme of the story ▪ The storyteller must use a clear voice to convey the connotation of the story ▪ Storytellers should apply the correct technology to create the story ▪ The story media should connect the audience to the story or transport the audience into the story.	▪ The model is silent on the evaluation of storytelling.

		▪ The story should be made with fewer media elements to convey the meaning.	
Tenh *et al*. (2012)	▪ "Perspective ▪ Intension ▪ Personal ▪ Dramatical question ▪ Engagement ▪ Articulation ▪ Soundtrack ▪ Minimal ▪ Tempo ▪ Story map ▪ Expression ▪ Significant Content ▪ Collaboration ▪ Communication ▪ User contribution" (Tenh *et al.,* 2012)	▪ The storyteller's position on the story ▪ The story should have an objective ▪ The storyteller must personalize the story to make the audience feel more emotionally involved. ▪ A dramatic question is a statement at the beginning of the story that creates a question in the viewer's mind. ▪ The story should evoke a strong emotional feeling in the audience ▪ The storyteller's voice must be	▪ The model did not include hardware, software, or multimedia elements. ▪ The model is silent on the evaluation of storytelling.

		clear to convey the meaning of the story ▪ The soundtrack should be enjoyable to connect the viewers to the story ▪ The story should not be too long to create boredom ▪ The story's pace must neither be too slow nor too fast, but must be balanced for viewers to understand the story ▪ Identification of the story characters, plot, setting, conflict, and point of view ▪ The storyteller's language must be meaningful to the audience ▪ Storytellers should select	

		content to match the theme of the story ▪ Storytellers should collaborate with others to create the story. ▪ The story should be interactive. ▪ Viewers should be able to take part in the storytelling.	
Chang *et al.* (2023)	▪ "Brainstorming ▪ Selection ▪ Forming ▪ Evaluation and Reflection" (Chang *et al*., 2023)	▪ Discuss and determine the content of the story ▪ Upload the story content into the robot ▪ Programming of robots ▪ Presentation and evaluation of the story	▪ The model is silent on the requirements analysis of a story. ▪ This model was designed for robot storytelling but lacks testing before story presentation.

Summarizing the review of conceptual models proposed by experts in digital storytelling, it is evident that most of the models presented by experts are relevant to oral storytelling. Most of these model elements inform developers of the quality features of storytelling. In addition, most of the models are not favourable for storytelling applications for training and instructional delivery. This assertion is because the models do not capture evaluation as part of the elements. Training and instructional delivery require assessment at the end of the delivery to assess the outcome of the activities. Most digital storytelling models mentioned above are also unfavourable to robot storytelling developers. The models lack requirements analysis and testing, which are relevant in any programming module, software development, and robot storytelling development.

The proposed robot storytelling model considers the requirements for developing robot storytelling. The requirement element of the proposed robot storytelling model recommends that developers select a topic for the storytelling and define its purpose and objectives. This activity enables developers to identify the relevant media elements needed to create digital stories. The requirements for the storytelling will also recommend to the developer the selection of the robot that will be used for the storytelling. The type of robot selected will inform the developer of the features and programming tools required for programming.

The proposed model will also include an evaluation of storytelling, a necessary activity or element in instructional delivery and training programs. Evaluation enables developers to assess the training or learning outcomes and determine whether the desired outcomes were achieved. Testing is a crucial element in any programming module; hence, the proposed model will include testing. Testing will enable developers to program the robot to a satisfactory level before rolling it out to the audience.

Hence, the absence of these essential elements necessitates the development of a conceptual model for robot storytelling, which addresses this gap to enhance existing storytelling models. The proposed model will therefore address the gap by analyzing existing research on robot storytelling to identify the procedures used in developing their robot storytelling.

2.3. **A Scoping Review of Robot-Assisted Digital Storytelling**

2.3.1. Introduction

This section presents a scoping review of articles and conference papers on robot storytelling to identify models of robot storytelling that have been published. The review uncovered the research gaps in robot storytelling and its models. The review adopted the method prescribed by Tricco *et al*. (2018) and the framework proposed by Arksey and O'Malley (2005). Arksey and O'Malley (2005) assert that a scoping review aims to pinpoint deficiencies in the evidence base where research is absent. Arksey and O'Malley (2005) also contended that a scoping study advances the dissemination process by summarizing the current literature on the general condition of research activities. This study conducted an extensive search for published reports on robot-based storytelling models in Scopus, Lens, and Web of Science, but found no relevant published reports. Hence, the decision was made to employ a scoping assessment to identify research gaps in the robot-based storytelling model.

2.3.2. Methods and Materials

The scoping review study selected thirty robot storytelling research articles and conference papers from Scopus, Web of Science, and Lens. The records (articles and conference papers) were selected based on specified inclusion and exclusion criteria. About 235 records were initially retrieved from the three databases. These records were screened to obtain thirty records used for the scoping review. The final thirty records were charted to extract the data relevant to the review. The extracted data was tabulated under various headings.

2.3.3. Results

The data charted in the methods and materials section was collated, summarized, and reported using frequency tables and column charts. The collation and summaries were done on the following headings: population types, conceptual models, theoretical/methodological frameworks employed by the articles, types of study interventions, and outcomes.

2.3.4. Discussion

The scoping review results were discussed under the following headings: trend in robot storytelling, robot storytelling models, methodological frameworks, and educational implications. The trend in robot storytelling was discussed based on the interventions of the selected research articles or papers. The robot-based conceptual models and methodological frameworks were also discussed, based on the models and frameworks identified in the selected research papers. Finally, the educational implications were discussed based on the impacts of the robot storytelling research employed to deliver instructions.

2.3.5. Findings

The scoping review found that few robot storytelling models exist, and none provide a guide for delivering robot storytelling instruction or training. Additionally, none of the discovered models include essential components such as storytelling analysis, programming, testing, and evaluation, which are fundamental to any programming instruction. The scoping review, therefore, recommended the need for more robot storytelling models to guide educators in creating robot storytelling to deliver instructions.

Readers can access the full scoping review article using the following references to search in Scopus, Google Scholar, and other databases.

Essien, G. and Parbanath, S.S., 2024. Exploring the World of Robot-Assisted Digital Storytelling: Trends, Models, and Educational Implications. *Journal of Information Technology Education: Research*, *23*, p.027.

2.4. Summary

The review discussed digital storytelling and its application in our everyday lives. Five leading platforms for creating digital storytelling were discovered: social media platforms, robot platforms, online/web-based platforms, computer-based software platforms, and mobile device software platforms. The review also identified models for creating digital storytelling proposed by earlier researchers in the field of digital storytelling. However, those models are not suitable for creating robot storytelling. Ultimately, the scoping review in this chapter identified a gap in digital storytelling, which led to the selection of this thesis topic.

CHAPTER THREE

An Overview of Humanoid Robot Technology

This chapter presents a short overview of humanoid robot technology. Its purpose is to enlighten readers about the robot’s components and functions, enabling them to understand the robot's operations in digital storytelling.

3.1 Robotics and Robot

Robotics: Robotics encompasses the examination of technologies related to the design, construction, and application of robots (Robotics, 2015).

Robot: A robot is a mechanical device designed to execute manipulation or locomotion tasks autonomously (Sandler, 1999). A robot is also a programmable electromechanical device that can perform tasks without human intervention. Robotics experts have not reached a consensus on the definition of the term "robot." However, most definitions in different literature mention that a robot is a programmable or software-controlled device capable of carrying out a task without being controlled by humans. Robots can be classified based on the environment in which they operate (e.g., industrial robots, space robots, laboratory robots) or their structural design (e.g., humanoid robots, animaloid robots). Industrial robots are engineered to transport materials, components, equipment, or specialized apparatus via programmable movements, executing a wide range of tasks (Sandler, 1999). A humanoid robot possesses a bodily structure that mirrors a person's (Kajita *et al*., 2014). The majority of humanoid robots are additionally classified as social robots. Social robots are engineered for human interaction; an example is the Pepper robot. The primary structural elements of a robot include a mechanical frame, a microcontroller, sensors, a power supply, and actuators. The subsequent sections provide an overview of the primary components of humanoid robots.

3.2 Humanoid Robot Body Parts

Humanoid robots possess bodily systems that are analogous to those of humans (Kajita *et al*., 2014). The robot's body consists of the head, torso, arms, and legs. Figure 3.1 depicts an instance of a humanoid robot. Most humanoid robots have body structures similar to those shown in Figure 3.1. The head contains devices like a camera, microphone, and tactile sensors. The placement of the sensors depends on the manufacturer's style and discretion. The head is connected to the torso with a joint. Most of the robot's torso contains a microcontroller or embedded computer that interprets information and facilitates decision-making. A battery is also located in the torso of the robot, providing power to the microcontroller, which enables it to carry out its duties. The arms of the robot consist of three joints that join the links of the arms. The legs of the robot are also comprised of three joints that connect the links of the legs. All joints on the robot, including the neck joint, contain actuators that move the links connecting to the joints. Both arms and legs contain tactile sensors that enable the robot to sense anything it physically comes into contact with. The remainder of this section provides a brief description of some humanoid robot body parts.

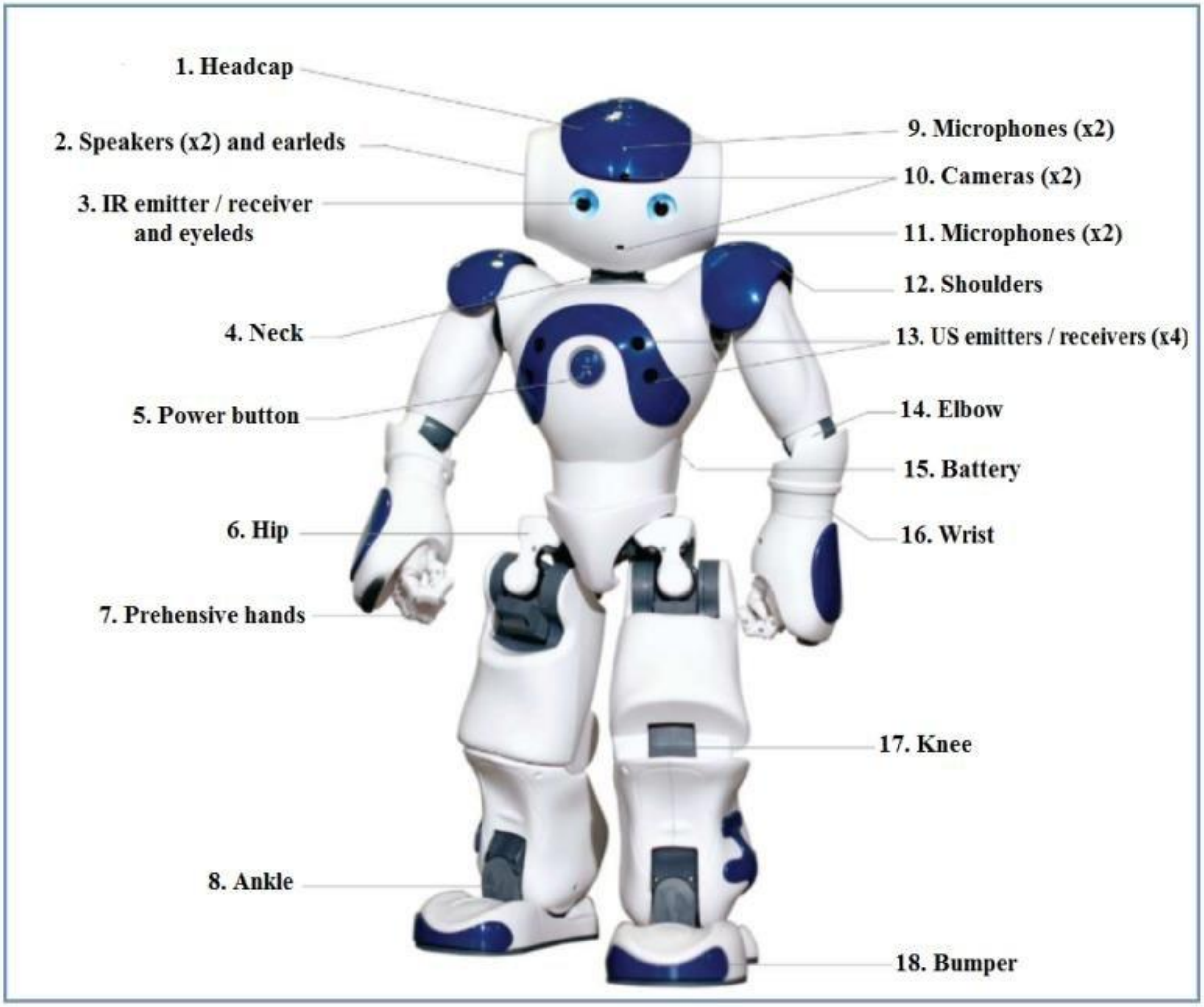

Figure 3.1: Humanoid Robot (Tuna & Tuna, 2019)

Joints: Joints produce relative motion between adjacent links in robot design. The main types of joints are linear, orthogonal, rotational, twisting, and revolving. The robot skeleton consists of joints and links. Links are the rigid parts between joints (Ramachandran *et al.*, 2017).

Manipulator: A manipulator is a robotic arm, often composed of interconnected segments designed to grip and manoeuvre things, usually exhibiting several degrees of freedom (DOF) (Sandler, 1999). The manipulator in humanoid robots is also known as the robot arm (Sandler, 1999). The manipulator is mounted to the robot body, which consists of the arm and the end effector (hand) (Sandler, 1999). The characteristics of manipulators depend on the purpose of the robots (Sandler, 1999).

End effector: The end effector is the component of a robot that is linked to the wrist joint, allowing it to grasp objects or perform its intended function (Ramachandran *et al*., 2017). In industrial robotics, end effectors can be classified into two categories: tools and grippers (Ramachandran *et al*., 2017). Grippers are used to grasp and handle objects, whereas tools are employed in industry for tasks such as welding, spraying, and cutting (Ramachandran *et al*., 2017). Humanoid robots, which serve as social robots, have end effectors similar to human hands (Ramachandran *et al*., 2017). Figure 3.1 shows a humanoid robot's prehensile hands (end effectors).

Degrees of freedom: The various directions in which a link attached to a joint can move are called degrees of freedom (DoF) (Ramachandran *et al*., 2017). Most robotic joints have three to six degrees of freedom (Ramachandran *et al*., 2017). Each joint may offer one or several degrees of freedom (Ramachandran *et al*., 2017). However, a joint agreement may not increase freedom, as it occurs when two or more joints are coupled, allowing only simultaneous movement (Ramachandran *et al*., 2017).

Robot Computer: Robots use small computers called microcontrollers, which are embedded into the robot to control its activities (see Figure 3.2). A microcontroller can be described as a small computer on a small board or a single chip that contains a processor, memory, and input/output ports. Information from sensors serves as input to this computer, which processes the data, and the output is sent to devices, such as actuators, depending on the nature of the output. The microcontroller instructs all actions carried out by the robot. Arduino and Raspberry Pi are examples of microcontrollers used in robotics (Braunl, 2003).

Figure 3.2: Robot Microcontroller (Robo Robotics, 2012)

2-Legged or Bipedal Robot: Two-legged robots, also known as bipedal robots**,** walk on two legs like humans. They can move on various surfaces and in environments designed for humans. Short and wide bipedal robots can be used to move heavy loads. However, tall bipedal robots are challenging to build, requiring balancing circuits, quick motions, and precise construction. (Robotics, 2015).

Wheeled robots: Wheeled robots typically possess between 3 and 6 wheels, excluding wheels used for feedback (Robotics, 2015). Two types of robot wheels are powered and unpowered (Robotics, 2015). Powered wheels utilize motors to propel the robot in forward and backward directions (Robotics, 2015). Unpowered wheels maintain the robot's equilibrium by establishing ground contact and facilitating movement (Robotics, 2015). Wheeled robots are easier to build than legged robots; however, they require smooth surfaces (Robotics, 2015). Figure 3.3 shows a Pepper humanoid robot with unpowered wheels.

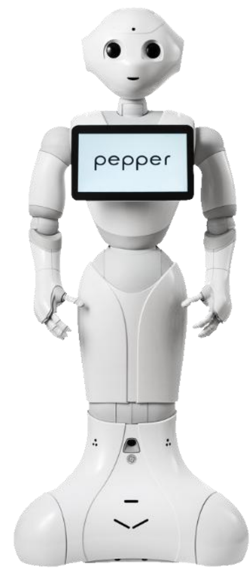

Figure 3.3: Pepper humanoid robot (Guizza, 2014)

3.3. Sensors

Sensors enable a robot to perceive its physical environment, gathering information about itself and its surroundings (Mataric, 2007). Sensing and perception refer to the process of receiving environmental information through sensors (Mataric, 2007). A sensor identifies and reacts to specific inputs, such as light, temperature, pressure, and motion, and converts them into quantifiable outputs (Mataric, 2007).

Various categories of sensors are employed in robotics. Some sensors locate objects in the robot's view, and others measure the distance to the nearest object. Sensors are classified into the following groups: proprioceptive and exteroceptive sensors (Solutions, 2007). They are also categorized into passive and active sensors (Solutions, 2007). Another sensor categorization is based on the type of output signal from the sensor, and this classification is made up of digital and analog sensors (Solutions, 2007).

Proprioceptive sensors: Proprioceptive sensors internally measure quantities within the robot (Solutions, 2007). Values measured by this sort of sensor include motor speed, wheel load, robot arm joint angles, and battery voltage (Solutions, 2007).

Exteroceptive sensors: Exteroceptive sensors get data from the robot's surroundings (Solutions, 2007). This sensor can quantify distance, light intensity, and sound amplitude (Solutions, 2007).

Passive sensors: Passive sensors quantify the ambient energy impinging on the sensor (Solutions, 2007). Instances of passive sensors encompass temperature probes, microphones, and CCD (charge-coupled device) or CMOS (complementary metal-oxide semiconductor) cameras (Solutions, 2007).

Active sensors: Active sensors transmit energy into the environment and measure the environmental response (Solutions, 2007). Active sensor examples encompass wheeled quadrature encoders, ultrasonic sensors, and laser range finders (Solutions, 2007).

Analog sensors: Analog sensors produce analog output signals (Braunl, 2003). Analog sensors in robotics need analog-to-digital converters to produce digital output signals that a microcontroller can process (Braunl, 2003). A microphone is an example of an analog sensor (Braunl, 2003).

Digital sensors: Digital sensors generate digital output signals. Digital sensors are more accurate but usually more complex than analog ones (Braunl, 2003). An example of a digital sensor is a digital camera (Braunl, 2003).

3.3.1 Standard Sensors Used in Robotics

Ultrasonic Distance Sensors: Ultrasound refers to sound waves with frequencies exceeding 20,000 Hz, which surpass the upper limit of human auditory perception (Ben-Ari & Mondada, 2017). Ultrasound is also called sonar, an abbreviation for **so**und **na**vigation and **r**anging. Therefore, ultrasound sensors are also sonar sensors (Mataric, 2007). There are two conditions where the transmission of sound performs better. These conditions occur at night and in water. As a result, an underwater robot uses ultrasound to detect objects in its path. Terrestrial robots utilize ultrasound to ascertain the distance to the nearest item in their trajectory. A robot transmits an ultrasound signal to the closest object and receives the reflected signal (Ben-Ari & Mondada, 2017). To determine the distance to the object, the robot measures the time it takes the signal to travel to the object and reflect from it (Ben-Ari & Mondada, 2017). With this method, the robot's microcontroller uses the equation $S = \frac{1}{2}vt$, "where s is the distance, v is the velocity of the signal, and t is the elapsed time between sending and receiving the signal" (Ben-Ari & Mondada, 2017). The image in Figure 3.4 shows an ultrasonic distance sensor.

Figure 3.4: Ultrasonic Distance Sensor (Studica, 2025)

Infrared Proximity Sensors: Infrared light possesses a wavelength that exceeds the red segment of the visible light spectrum (Ben-Ari & Mondada, 2017). The human eye perceives light wavelengths ranging from 390 nm to 700 nm (Ben-Ari & Mondada, 2017). However, infrared light has a wavelength between 700 and 1000nm (Ben-Ari & Mondada, 2017). Consequently, infrared light remains imperceptible to the human eye (Ben-Ari & Mondada, 2017). Humans can perceive the warmth of infrared radiation from sources such as the sun.

Proximity sensors (Figure 3.5) utilize infrared light to detect the presence of an object by measuring the intensity of the light reflected from it (Ben-Ari & Mondada, 2017). Light intensity diminishes with the square of the distance from the source, and this correlation can be utilized to estimate the object's distance. Distance measuring accuracy is compromised due to the varying light reflection properties of different coloured surfaces. Hence, the name is infrared proximity sensors, not distance sensors (Ben-Ari & Mondada, 2017).

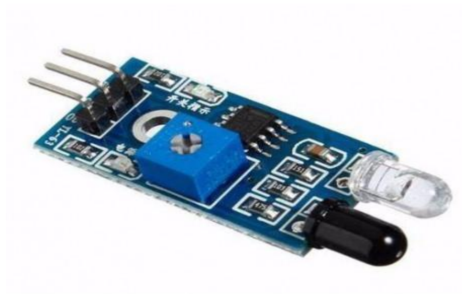

Figure 3.5: Infrared Proximity Sensor (Makerlab, 2025)

Optical Distance Sensors: Light signals are used to compute the distance from an object using the same equation as ultrasonic distance sensors, but v in the equation represents the speed of light (Ben-Ari & Mondada, 2017). The distance is computed by calculating the time between sending and receiving it. Laser light is predominantly utilized in optical distance sensors due to its coherence, which enables the detection and measurement of distances to remote objects (Ben-Ari & Mondada, 2017). Figure 3.6 presents an image of the optical distance sensor.

Figure 3.6: Optical Distance Sensor (Leuze, 2025)

Tactile Sensors: Tactile sensors allow robots to perceive physical contact with objects. In tactile sensing, a force distribution is quantified utilizing a densely arranged array of force sensors (De Silva, 2016). Tactile sensors also enable robots to sense and grasp objects. Robots utilize touch sensors to examine surface profiles and joints for faults, manage materials, transfer components, assemble parts, and identify and gauge components in manufacturing applications (De Silva, 2016). The most basic tactile sensors consist of conductive polymers, elastomers, or semiconducting polymers, referred to as piezoresistive sensors or force-sensitive resistive (FSR) sensors (Ida, 2013). A bumper switch is a tactile sensor used in the legs or wheels of a robot to detect when the robot hits a wall (see Figure 3.7).

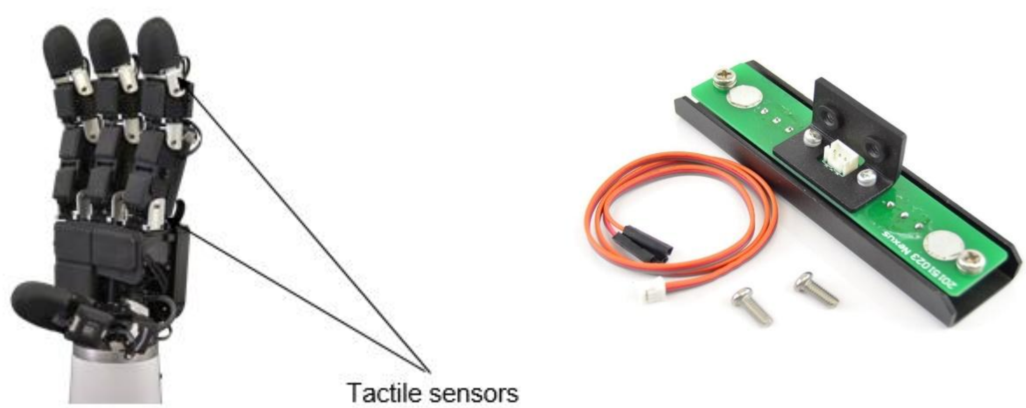

Figure 3.7: Robot hand with tactile sensors (left) (Wikipedia, 2025) and bumper sensor (right) (RobotShop, 2025)

Digital Camera (image sensor): Digital cameras contain sensors that detect images of objects. They are, therefore, used as image sensors in robots (Figure 3.8). A digital camera features a matrix of semiconductor elements that are responsive to the luminosity of light emanating from an object through the camera lens (De Silver, 2016). Digital cameras utilize charge-coupled device (CCD) technology or complementary metal-oxide semiconductor (CMOS) technology for their image sensors (De Silver, 2016). CCD technology produces superior image quality compared to CMOS technology (De Silver, 2016). Nonetheless, irrespective of the technology employed in the camera image sensor, a computer can capture and process the image (De Silver, 2016).

Figure 3.8: Camera used in robotics (RobotShop, 2025)

Microphone: Robots use microphones to detect sound or voice and use algorithms to interpret the voice. Microphones convert sound energy into electrical energy. Microphones are made from different technologies. The different types of microphone technologies are carbon, magnetic, ribbon, and capacitive (Ida, 2013). Most robots use electret microphones, a variation of the capacitive microphone technology (see Figure 3.9).

Figure 3.9: Electret microphone (Sparkfun, 2025)

Encoders: An Encoder is a kind of sensor that converts angular displacement or velocity into an electrical impulse or digital quantity (Li & Liu, 2019). Encoders determine a motor shaft's position, velocity, direction, or mechanical motion. They provide the information required for the precise control of robots (Figure 3.10). There are four types of encoders: optical, magnetic, inductive, and capacitive encoders.

Magnetic encoders are often constructed utilizing Hall sensors that operate on the principle of the Hall Effect, which generates a voltage difference in response to an external magnetic field (Sanchez, 2015). Optical encoders utilize optocouplers (Sanchez, 2015). These devices transmit and receive light, functioning as a switch. An infrared LED emits light that saturates a photodetector. Optical encoders are the most precise category of encoders. Inductive encoders function on the same principle as AC transformers to ascertain location or velocity (Sanchez, 2015). Capacitive encoders utilize the electrical characteristic of capacitance to deliver measurements (Sanchez, 2015). Capacitance refers to the capacity of a material thing or device to accumulate electric charge (Sanchez, 2015). It is quantified by the charge resulting from a variation in electric potential (Sanchez, 2015).

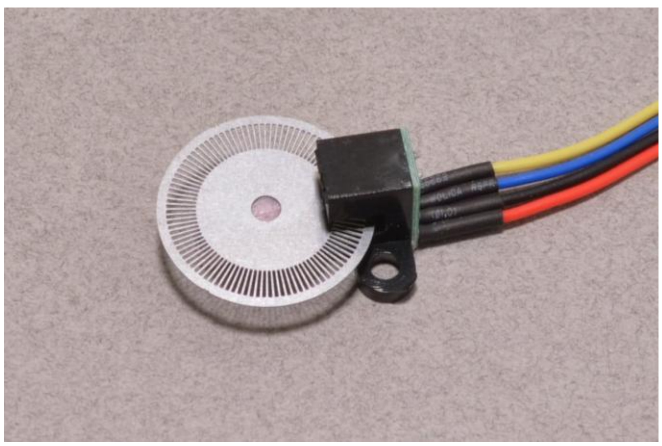

Figure 3.10: Wheel Encoder Sensor (BCRobotics, 2025)

Gyroscope: A gyroscope sensor measures or maintains a robot's orientation and angular velocity in space (Figure 3.11). A gyroscope is used to track the robot's walking and balancing. The Gyroscope sensor lets the robot measure its turn rate in degrees per second. The robot also uses a gyroscope sensor to monitor its direction of travel and make sure it travels in a straight line or turns accurately (Ida, 2013)

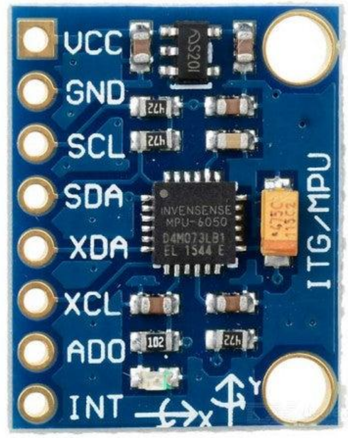

Figure 3.11: Gyroscope Sensor (Hackatronic, 2025)

3.4. Actuators

An actuator is a device that facilitates the movement of a mechanical system (Brown, 2017). An actuator necessitates a control signal and an energy supply to induce motion in a mechanical system (Brown, 2017). The energy can be classified as electric current, hydraulic, or pneumatic pressure (Brown, 2017). The control system is a static mechanical, electrical, or software system. Actuators are the elements of a robot that enable it to walk. Actuators are also utilized in the robot's manipulators to facilitate the end effectors in grasping objects. In short, all moving parts of the robots use actuators for their operations. The primary actuators are electric, hydraulic, and pneumatic (Brown, 2017). Actuators are also known as drivers in robotics.

3.4.1. Types of Actuators Used in Robotics

Hydraulic Actuators: Hydraulic actuators utilize pressured oil to produce motion (Nehmzow, 2003). Hydraulic actuators produce significant power and precise movements, yet they are typically cumbersome, unclean, and costly for mobile robots (Nehmzow, 2003). A hydraulic actuator (see Figure 3.12) is a cylinder or fluid motor that uses hydraulic power for mechanical operation (Brown, 2017). The cylinder is a hollow tube that permits the sliding motion of a piston. Fluid pressure is delivered to either one side of the piston or both sides. Single-acting refers to applying fluid pressure on only one side of the piston (Brown, 2017). Double-acting operates when pressure is exerted on both sides of the piston; any pressure differential between the two sides displaces the piston in one direction or the other (Brown, 2017). The hydraulic actuator produces linear, rotary, or oscillatory motion (Brown, 2017). Hydraulic actuators are used on large industrial robots. However, most industrial robots utilize electric actuators because they perform better than hydraulic actuators (Todd, 1986).

Figure 3.12: Hydraulic Actuator (Elprocus, 2025)

Pneumatic Actuators: Pneumatic actuators function through the interplay of air-generated force and spring force (Brown, 2017). They transform energy generated by vacuum or high-pressure compressed air into linear or rotary motion (Brown, 2017). A pneumatic actuator comprises a piston, a cylinder, and valves or ports (refer to Figure 3.13) (Brown, 2017). The piston is encased by a diaphragm or seal, which retains the air in the upper section of the cylinder (Brown, 2017). The air pressure exerts a downward force on the diaphragm, displacing the piston below and activating the valve stem connected to the internal components of the actuator (Brown, 2017). Pneumatic actuators are used in more miniature robots and for simple material transfer applications. The robot's end effector employs pneumatic actuators for gripping objects. Several pneumatic actuators exist, including pneumatic grippers and rotary actuators (Brown, 2017).

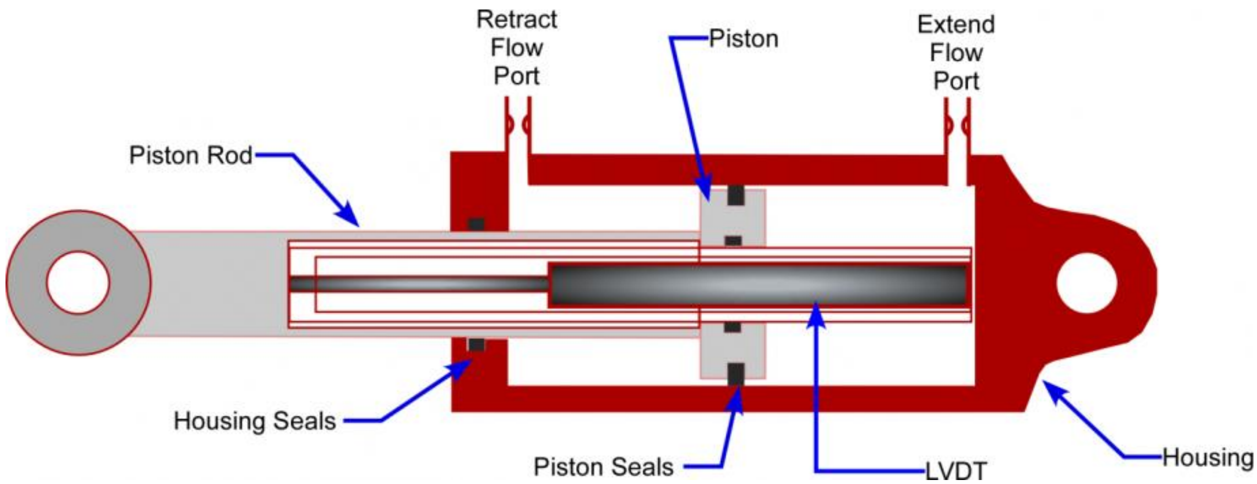

Figure 3.13: Pneumatic actuator (Robotics Tomorrow, 2025)

Electric Actuators: An electric actuator uses an electric motor to convert electrical energy into mechanical motion. Electric actuators are used to move robots' joints for high-speed manipulations. Electric actuators are the preferred actuators in modern robotics. The standard motors used in electric actuators are DC, stepper, and servo motors.

DC Motors: A DC motor transforms direct current (DC) energy into rotational mechanical energy (De Silva, 2016). A substantial portion of the torque produced in the motor rotor (armature) is accessible for driving an external load (De Silva, 2016). DC motors are used in the design and construction of robot manipulators and disk drives (De Silva, 2016). This motor type (Figure 3.14) is widely used in robotics due to its compact dimensions and substantial energy output (De Silva, 2016). They are highly effective for energizing the driving wheels of robots (De Silva, 2016).

Figure 3.14: DC Motor (Association for Advancing Automation, 2025)

Stepper Motors: A stepper motor is an electric motor that operates in distinct increments of a predetermined magnitude (Brown, 2017). A stepper motor can generate continuous rotation at a regulated speed or advance by a specified angular increment (Brown, 2017). The phrases "stepper motor," "stepping motor," and "step motor" are synonymous and can be used interchangeably (Todd, 1986). Stepper motors (Figure 3.15) are typically compact, possess restricted torque and speed, and are commonly employed in low-performance robots for instructional purposes (Todd, 1986). Nevertheless, specific robust stepper motors are utilized for the wheels of specific mobile robots (Todd, 1986).

Figure 3.15: Stepper Motor (Indiamart, 2025)

Servo Motor: A servo motor is an actuator, either rotary or linear, that accurately regulates the angular or linear position, velocity, and acceleration of a mechanical system (Servomotor, 2023). A servo motor is a self-contained assembly that includes a motor, a gear train, a position encoder, and an integrated control system, all of which work together to convert multiple motor rotations into increased torque and determine the output shaft's location (Brown, 2017). The position encoder transforms linear or rotary motion into an electrical signal that conveys information regarding position, velocity, and direction of movement (Appin Knowledge Solutions, 2007). A servo motor (see Figure 3.16) consists of three wires: power, ground, and control (Appin Knowledge Solutions, 2007). The power and ground cables are linked to a power supply (Appin Knowledge Solutions, 2007). The control signal comprises a sequence of pulses that denote the intended location of the shaft (Appin Knowledge Solutions, 2007). Each pulse signifies a singular position directive. The duration of a pulse in time correlates with the angular location (Appin Knowledge Solutions, 2007). Standard pulse durations vary from 0.7 to 2.0 milliseconds for a servo shaft's complete range of motion (Appin Knowledge Solutions, 2007). Most servo shafts possess a rotational range of 180 degrees (Appin Knowledge Solutions, 2007). Servos are used to move the legs of humanoid robots.

Figure 3.16: Servo Motor (Oz Robotics, 2025)

3.5. Robot Programming

A robot program is a set of programming instructions that instruct the robot's hardware on what to do. The robot program enables the manipulator to carry out its task, allowing the robot to walk or perform any other activity. The robot program is loaded into the robot's controller memory and runs for it to control the hardware. There are two methods of programming robots. These methods are lead-through programming and off-line programming.

3.5.1. Lead-through Programming

Lead-through programming is a method of robot programming in which a robot's manipulator is guided through the necessary motions to do a task, which are recorded in the robot's controller memory for future replay (Ramachandran *et al*., 2017). Two categories of lead-through programming exist: powered lead-through programming and manual lead-through programming (Ramachandran *et al*., 2017).

In powered lead-through programming, the operator instructs the robot's manipulator via a teach pendant (see Figure 3.17). The teach pendant is a handheld control apparatus featuring a keypad that connects to the robot via a cable or wireless technology. The teach pendant or control box facilitates the manipulation of the robot's movements to execute tasks while concurrently documenting these movements in the robot's controller memory. After the first cycle of the manipulator's activity, the teach pendant is disconnected from the robot, and the manipulator proceeds with subsequent cycles without further user intervention. The powered lead-through programming method enables users to program robots for tasks such as spot welding, machine loading, and unloading (Ramachandran *et al*., 2017).

Figure 3.17: Teach Pendant (Yaskawa, 2025)

The manual lead-through approach necessitates the operator to physically guide the manipulator along the designated path to perform its function. Simultaneously, the robot's controller documents the manipulator's movements. This approach is advantageous for continuous route activities that require curvilinear movements of the robotic arm during the motion cycle. After completing the first cycle of the work, the robot carries out subsequent cycles without the operator's intervention. The manual lead-through programming method is applied in spray painting and continuous arch welding (Ramachandran *et al*., 2017).

3.5.2. Off-line Programming

Offline programming is a technique for programming a robot, but the programmer does not utilize the robot, unlike lead-through programming (Ramachandran, Lazarus, and Lakshmi, 2017). Here, the programmer develops the program on a computer and later uploads it to the robot's memory. This method involves using textual programming languages, such as C++ and Python, to write the program or utilizing proprietary application software specifically designed for programming the robot. Most proprietary application software allows programmers to test the program through simulation before uploading it to the robot's memory. The offline programming technique conserves production time that would otherwise be wasted on instructing the robot on a new task using the lead-through programming approach (Ramachandran *et al*., 2017).

3.6. Summary

The chapter discusses the primary components of a robot's structural frame, including the head, manipulators, joints, and legs. The review also discussed the primary electronic components, including microcontrollers, sensors, and actuators. The chapter mentioned the standard sensors and actuators used in the robotics industry. Finally, the chapter discusses the two methods of robot programming: lead-through programming and offline programming.

CHAPTER FOUR

Methodology for the Research

This chapter examines the core principles that inform the design and implementation of the thesis. The subjects addressed encompass research paradigms, foundational pillars of paradigms, classifications of paradigms, and the specific paradigm employed in this study. The chapter examines research methodologies, the strategies inherent to each method, and the method selection for this research endeavour. The chapter ultimately addresses the ethical considerations pertinent to this research endeavour, sampling strategy, and participant recruitment.

4.1. Research paradigm

A research paradigm constitutes a collection of beliefs and consensus among scientists regarding the comprehension and resolution of problems (Rahi, 2017). According to Willis (2007), it is a comprehensive set of beliefs, a worldview, or a framework that guides research and practice in a field. Fraser and Robinson (2004) also describe a research paradigm as a collection of attitudes regarding specific problems and consensus on investigating these issues. In addition, Guba (1990) defines it as a set of ideas that directs actions. These definitions suggest that a research paradigm encompasses the researcher's perspective on the essence of the study topic, the identification of the issue, and the methodologies for addressing it, including data collection and analysis. A research paradigm is based on ontology, epistemology, methodology, and axiology (Kivunja & Kuyini, 2017).

Ontology of a paradigm: Ontology is a philosophical discipline that focuses on the premise that certain entities are meaningful or genuine, or that the intrinsic nature of the social phenomenon under investigation is authentic (Scotland, 2012). It pertains to the researcher's presuppositions on a study problem, asserting that the examined issue is rational or exists. It assists the researcher in conceptualizing the structure and essence of reality, as well as the extent of knowledge attainable regarding it (Kivunja & Kuyini, 2017). Philosophical assumptions regarding the nature of reality are crucial for understanding how a researcher interprets the collected data. These assumptions, conceptions, or propositions guide your understanding of the study problem, its importance, and your potential method to contribute to its resolution (Kivunja & Kuyini, 2017). Ontology aims to ascertain the essence of the fundamental concepts that form the themes examined, thereby elucidating the meaning inherent in research findings. Researchers may inquire about the nature of reality within the realm of ontology. What is the essence of the scenario under examination? Kivunja & Kuyini (2017).

Epistemology of a paradigm: Epistemology is the philosophical discipline that examines the nature of knowledge and the mechanisms by which knowledge is acquired and validated (Gall *et al*., 1996). Epistemology delineates how humans acquire knowledge and ascertain truth or reality (Kivunja & Kuyini, 2017). Cooksey and McDonald (2019) define epistemology as the criteria for what constitutes knowledge in the world. This component of the research paradigm addresses the essence of information derived from research and the methods by which this knowledge is acquired and conveyed to others. Epistemology examines the nature of expertise a researcher might cultivate to enhance, expand, and deepen comprehension within a particular research domain (Kivunja & Kuyini, 2017). When examining the epistemology of a study paradigm, the researcher must inquire whether knowledge can be acquired or directly experienced. (Kivunja & Kuyini, 2017). Another pertinent inquiry is: What is the relationship between the researcher and the individuals who supply the information that forms the basis of knowledge or the sources of that information? (Kivunja & Kuyini, 2017). Obtaining answers to these inquiries helps the researcher situate themselves within the research context and adopt the appropriate methodology for data collection.

Methodology of a paradigm: Methodology denotes the study design, methods, tactics, and procedures employed in a meticulously organized investigation to discover information (Keeves, 1990). The methodology encompasses data gathering, participant selection, the instruments used, and data analysis (Kivunja & Kuyini, 2017). It also contains the assumptions established, the limits faced, and the methods employed to address them (Kivunja & Kuyini, 2017). The primary inquiry a researcher must have when evaluating a paradigmatic technique is: How will I obtain the necessary data, knowledge, and comprehension to solve the research question and enhance understanding? (Kivunja & Kuyini, 2017). The methodology delineates the rationale and progression of the systematic approach employed in a research project to get insights into the research challenge (Khatri, 2020).

Axiology of a paradigm: Axiology pertains to the ethical considerations that inform the philosophical methodology for determining value judgments or appropriate resolutions (Finnis, 2011). It involves defining, evaluating, and understanding concepts of moral and immoral behaviour related to the research (Kivunja & Kuyini, 2017). Axiology examines the value a researcher should assign to several elements of a research endeavour, including the participants, the data, and the audience for the research findings (Kivunja & Kuyini, 2017). The primary inquiry a researcher poses within the axiology of a paradigm is: what constitutes the essence of ethics or ethical conduct? (Kivunja & Kuyini, 2017). In addressing this inquiry, a researcher must contemplate safeguarding participants, their rights, and moral considerations (Kivunja & Kuyini, 2017). Furthermore, ethics necessitates honouring participants' decisions and considering ethnic and intercultural considerations (Kivunja & Kuyini, 2017).

4.1.1. Types of Research Paradigms

Researchers have proposed various research paradigms for use in conducting research projects. This study will discuss the four most common types of research paradigms: positivism, interpretivism, critical or transformative, and pragmatic paradigms.

Positivist paradigm: According to Alharahsheh and Pius (2020), positivist research focuses on the researcher's interaction with observable societal facts, leading to generalizations. It only highlights objective information and facts, free from human interpretation biases (Scotland, 2012). Research employing the positivist paradigm utilizes deductive reasoning, hypothesis development, hypothesis testing, provision of operational definitions, mathematical formulations, computations, extrapolations, and expressions to reach findings (Kivunja & Kuyini, 2017). The positivist paradigm aims to provide explanations and generate predictions based on quantifiable data (Kivunja & Kuyini, 2017). Positivists assert that valid knowledge can be acquired by observation and experimentation (Rahi, 2017). Positivists claim that a singular reality may be quantified and comprehended. Consequently, researchers employing the positivist paradigm are inclined to adopt quantitative methodologies in their investigations (Ulz, 2023).

Concerning the four pillars of the research paradigm previously mentioned, the positivist paradigm posits that its ontology is realism, asserting the existence of a singular reality. Realism posits that truth is objective, quantifiable, and measurable through processes independent of the researcher (Ugwu *et al*., 2021). Positivists likewise presume that their epistemology is objective. Objective epistemology asserts that human comprehension is acquired through the use of reason (Fadhel, 2002). Positivists adhere to an experimental technique (Kivunja & Kuyini, 2017). According to Smith and Heshusius (1986), the experimental method is a research approach that involves manipulating one variable to determine whether changes in that variable result in changes in another variable. For positivists, axiology equates to beneficence (Kivunja & Kuyini, 2017). Beneficence axiology mandates that all studies optimize positive outcomes for the research endeavour, humankind, and the research participants (Martens, 2015). The axiology of beneficence necessitates that research endeavours strive to avert or mitigate any potential risks, harm, or misconduct that may arise throughout the investigation (Kivunja & Kuyini, 2017). The positivist paradigm typically employs one or more criteria to authenticate research findings, including internal validity, external validity, dependability, and objectivity (Burns, 2000).

Interpretivist paradigm: This paradigm, also known as the constructivist paradigm, prioritizes understanding individuals and their interpretations of their surrounding environment (Ugwu *et al*., 2021). It aims to understand the subjective domain of human experience (Guba & Lincoln, 1989). Interpretivists assert the existence of numerous realities instead of a singular one (Ulz, 2023). The interpretivist paradigm aims to comprehend and elucidate individuals' thoughts and meanings within a specific setting (Kivunja & Kuyini, 2017). Emphasis is placed on understanding the subjects' perspectives under observation rather than those of the observers. Attention is also directed at comprehending individuals and their perceptions of the surrounding world (Kivunja & Kuyini, 2017). The interpretivist paradigm posits a subjectivist epistemology, a relative ontology, a naturalist methodology, and a balanced axiology (Kivunja & Kuyini, 2017).

Subjectivist epistemology posits that researchers derive meaning from data through personal cognition and interpretation during participant interactions (Kivunja & Kuyini, 2017). Subjectivist epistemology asserts that the researcher and subjects engage in an interactive process characterized by mingling, dialogue, questioning, listening, reading, writing, and documenting research findings (Kivunja & Kuyini, 2017). Relativist ontology posits that the researcher acknowledges the existence of multiple realities within the researched situation, which can be examined, interpreted, or reconstructed (Chalmers *et al*., 2009). As a participant observer, the researcher uses a naturalist approach to gather data through discourses, interviews, text messages, and reflection sessions (Carr & Kemmis, 2003). According to equitable axiology, the research findings will reflect the researcher's values and attempt to present a fair data analysis (Kivunja & Kuyini, 2017).

The criteria for validating research outputs under the interpretivism paradigm encompass credibility, dependability, confirmability, and transferability (Kivunja & Kuyini, 2017). Credibility denotes the degree to which facts and their interpretation are perceived as believable, trustworthy, or authentic (Kivunja & Kuyini, 2017). Dependability refers to the ability to consistently achieve outcomes or findings in similar situations (Kivunja & Kuyini, 2017). Confirmability denotes the degree to which others may validate the results of a research endeavour within the discipline (Kivunja & Kuyini, 2017). Transformability refers to researchers' efforts to provide sufficient contextual information about their studies, enabling readers to connect the findings to their specific setting or research context (Lincoln & Guba, 1985).

Critical paradigm: The critical paradigm, often referred to as the Transformative paradigm, employs both qualitative and quantitative methodologies to enhance the understanding of gaps in community relationships, advocate for social justice, and eventually facilitate transformative change (Ulz, 2023). This paradigm places its research in the framework of social justice concerns. At every level of occurrence, it seeks to address the political, social, and economic issues that lead to power dynamics, conflict, social oppression, and struggle (Kivunja & Kuyini, 2017). Transformative researchers assert that inquiry must be integrated with politics and a political agenda, encompassing an action agenda for reform that can potentially alter participants' lives, the institutions in which they operate, and the researchers themselves (Creswell, 2017).

The critical paradigm posits a transactional epistemology wherein the researcher engages with the participants. This framework presupposes the ontology of historical realism concerning oppression, a dialogic technique, and an axiology that honours cultural norms (Kivunja & Kuyini, 2017). The historical realism paradigm posits that reality exists independently of human perception. Nonetheless, it has been influenced by cultural, political, ethnic, gender, and religious variables that interact to form a social structure (Rehman & Alharthi, 2016). Transactional epistemology is inherently subjective, positing that no object can be investigated without being influenced by the researcher's experiences or knowledge (Rehman & Alharthi, 2016). The dialogic approach requires the researcher to involve participants in discourse, altering their perspectives on social structures and thereby undermining their intellectual and social assumptions (Rehman & Alharthi, 2016). To avert the marginalization of participants, researchers employ a collaborative methodology that involves subjects in formulating questions, collecting data, and analyzing it (Rehman & Alharthi, 2016).

Pragmatic paradigm: The pragmatic paradigm seeks to identify the most effective methodologies and procedures for addressing a research topic (Rahi, 2017). Advocates of the pragmatic paradigm argue that valid information can be acquired through a mixed-methods approach (Rahi, 2017). Pragmatism does not adhere to a singular philosophical system or conception of reality (Mackenzie and Knipe, 2006). The study question "central" dictates the selection of data collection and analysis procedures that are most likely to yield insights without allegiance to any alternative philosophical framework (Mackenzie & Knipe, 2006). Pragmatists assert that reality is ever-evolving in response to ever-changing circumstances (Ulz, 2023). This paradigm employs a framework most applicable to the research question being studied (Ulz, 2023). Both quantitative and qualitative techniques used by positivists and interpretivists are combined to solve a research problem (Ulz, 2023). Pragmatists assert that the most effective research method is the one that most adequately addresses the research issue (Ulz, 2023).

The pragmatic paradigm supports a relational epistemology, a non-singular reality ontology, a mixed methods methodology, and a value-laden axiology (Kivunja & Kuyini, 2017). Relational epistemology posits that the relationships in research are optimally defined by the researcher's judgment regarding the specific study (Kivunja & Kuyini, 2017). The non-singular reality ontology posits that no singular reality exists and that each human possesses distinct perceptions of reality (Kivunja & Kuyini, 2017). Mixed methods methodology integrates quantitative and qualitative approaches to address research issues (Kivunja & Kuyini, 2017). Value-laden axiology believes a research project should benefit humanity (Kivunja & Kuyini, 2017).

This thesis employed the pragmatic and Design Science Research paradigms to address the research problem in science and engineering projects.

4.1.2. Choice of research paradigm to underpin this study

This study uses the pragmatic research paradigm, integrating quantitative and qualitative methodologies to address a research problem. The study identified multiple research articles that developed robot storytelling. After analyzing the identified articles, it was discovered that researchers employ customized methods to build their robot storytelling systems. However, this study believes that there are common elements in the different articles used by robot storytelling developers that the study can identify to create the proposed model. Due to the qualitative and quantitative nature of the identified robot storytelling articles, this study adopted a pragmatic research paradigm to solve the research problem. The study employed a combination of content analysis and meta-synthesis to develop the proposed robot-assisted digital storytelling model. Content analysis and meta-synthesis are typical methods used in the interpretivist research paradigm. The study also evaluated the developed model using the experimental design method, a typical method employed under the positivist research paradigm. Consequently, the decision was made to utilize the pragmatic research paradigm, which combines the quantitative methodologies of the positivist approach with the qualitative procedures of the interpretivist framework.

4.2. Qualitative, Quantitative, and Mixed Methods Research

This section examines the three principal research methodologies for addressing research problems: qualitative, quantitative, and mixed methods. This study employed a mixed methods methodology under a pragmatic paradigm. However, both quantitative and qualitative approaches were discussed, followed by a mixed-methods research approach. The rationale is that the mixed-method approach integrates qualitative and quantitative research methodologies.

4.2.1. Qualitative Research Methods

A methodological approach known as qualitative research prioritises verbal information over numerical quantification in data collection and interpretation (Hammersley, 2012). It aims to examine and provide a thorough, comprehensive, and complete description of events based on non-numerical data (Oranga & Matere, 2023). Additionally, it clarifies and analyzes interpersonal connections, individual experiences, and societal standards (Oranga & Matere, 2023). There are six primary methodologies under qualitative research: grounded theory, ethnography, phenomenology, narrative, case study, and content analysis (Taherdoost, 2022). Below are brief descriptions of the methods.

Grounded Theory: Grounded theory formulates and develops theory from systematically acquired and studied facts (Oranga & Matere, 2023). The process involves creating a theoretical framework based on observations of a research population. This inductive research examines experiences and social interactions (Oranga & Matere, 2023). A researcher employing the grounded theory methodology may construct a theory to elucidate the events under investigation by observing the population (Oranga & Matere, 2023).

Ethnography/Ethnographic Design: This design originates from cultural and social anthropology, requiring the researcher to be immersed in the participants' environment

(Oranga & Matere, 2023). Through this methodology, the researcher or ethnographer examines a specific social or cultural group to gain deeper insights and employs various data collection techniques to generate a comprehensive account of phenomena observed during the research period. Consequently, ethnographical research aims for researchers to integrate themselves within the research population and document behaviours, actions, and events from an insider's perspective (Grossoehme, 2014).

Phenomenological Design: The philosophical discipline of phenomenology emphasizes people's subjective perceptions and experiences of reality. Without concluding, formulating hypotheses, or making assumptions based on other fields, the phenomenologist aims to understand and describe how different people perceive the universe (Oranga & Matere, 2023). A distinction between grounded theory and this design is that grounded theory seeks to formulate a theory based on social phenomena by analyzing many data sources. Conversely, phenomenology focuses on elucidating and depicting phenomena from the viewpoint of the individuals who encounter them (Oranga & Matere, 2023).

Narrative Design: Narrative Research integrates a series of events, typically from one or two individuals, to construct a coherent story or narrative that elucidates their viewpoints, emotions, and experiences regarding a phenomenon (Oranga & Matere, 2023). Narrative researchers engage with limited participant samples to elicit profound and expansive discourse, frequently empowering, liberating, and amplifying the voices of oppressed groups (Oranga & Matere, 2023).

Case Study Design: This is a comprehensive examination of the progression of a specific event, individual, or circumstance within a real-world setting (Oranga & Matere, 2023). Case studies are frequently employed to investigate and elucidate intricate medical diseases and societal issues, such as drug addiction and prostitution (Oranga & Matere, 2023).

Content Analysis: Content analysis is a technique for examining written, vocal, or visual communication messages (Mohajan, 2018). Leedy and Ormrod (2001) characterized content analysis as a meticulous and methodical evaluation of the contents of a specific set of materials to discern patterns, themes, or biases.

4.2.2. Quantitative Research Methods

Quantitative research uses natural science techniques to generate numerical data and empirical evidence (Ahmad *et al*., 2019). It seeks to determine causal linkages between two variables by mathematical, computational, and statistical techniques (Ahmad *et al*., 2019). Quantitative research employs statistical, logical, and mathematical methodologies to produce numerical data and concrete evidence. Taherdoost (2022) categorizes quantitative research into five distinct designs: survey research, descriptive research, experimental research, correlational research, and causal-comparative research.

Survey Research: A survey is a form of quantitative investigation wherein the researcher disseminates a set of questions to a sample of the target population (Ghanad, 2023). The primary objective of survey research is to acquire knowledge about a substantial population by examining a sample. A survey researcher formulates inquiries for participants and compiles their answers using percentages, frequency distributions, and various statistical methods (Ghanad, 2023). Survey research uses in-person, telephone, or online questionnaires to gather participant data. There are two types of surveys: cross-sectional surveys and longitudinal surveys. The cross-sectional survey is used when the researcher aims to collect data from a sample of the target population at a specific point in time (Ghanad, 2023). The longitudinal survey repeatedly gathers data from the target group and examines the temporal variations of the variable (Ghanad, 2023).

Descriptive Research: Descriptive research delineates the attributes of a population or phenomenon (Ghanad, 2023). The process entails collecting and analyzing data to describe it through frequencies, percentages, and averages (Ghanad, 2023). As is the case with other types of quantitative research, descriptive research encompasses quantitative data that can be gathered in numerical formats, such as test scores or the frequency with which an individual uses a particular feature in a multimedia program. Additionally, descriptive research may elucidate categories of data, such as gender or communication patterns, when employed in a group setting using technology (Ghanad, 2023).

Experimental Research: Experimental research involves a hypothesis and variables that can be quantified, computed, and analysed within a controlled setting (Ghanad, 2023). An experimental study seeks to identify a correlation and relationship between the dependent and independent variables (Ghanad, 2023). Experimental research design is also known as intervention research or group comparison (Ghanad, 2023). This technique is employed in quantitative research to evaluate whether an activity or material influences participants' outcomes (Ghanad, 2023). The researcher assesses the effect by allocating a particular set of activities to one group, termed the intervention group, while withholding that set from the other group (Ghanad, 2023).

Correlational Research: According to Ghanad (2023), correlational research is a method that identifies interrelated variables, allowing for a change in one variable to influence a change in the other variable. Correlational research investigates two variables to ascertain whether a statistically significant link exists between them without manipulation (Ghanad, 2023). For example, this research design can be used to study the relationship between diet and body weight.

Causal-comparative Research: This study strategy is employed to ascertain cause-and-effect correlations between independent and dependent variables post-event, wherein the researcher seeks to determine if the independent variable affected the outcome (Thomas & Zubkov, 2020). In causal-comparative design, researchers compare groups exposed to specific treatments/interventions with those not exposed to these treatments or interventions. Some examples of causal-comparative research problems include the effect of smoking on lung cancer and the impact of education levels on income.

4.2.3. Mixed Methods Research

Mixed methods research combines quantitative and qualitative methodologies within a single study or across several interconnected investigations (McLeod, 2024). Mixed-methods research is advantageous for addressing a research subject that necessitates a diverse approach, as it concurrently examines data trends and the nuances of individual experiences. Integration is fundamental in mixed methods research (McLeod, 2024). The integration notion refers to the deliberate amalgamation of quantitative and qualitative research, rendering them interconnected and collaboratively functioning to attain a shared study objective (McLeod, 2024). Employing both qualitative and quantitative methodologies in research can provide a more comprehensive understanding of a research phenomenon. Mixed methods enable researchers to integrate data actively, thus providing a more comprehensive perspective of the topic (Sharma *et al*., 2023). Researchers use mixed methods studies when a single data type is inadequate to resolve the study issue (Sharma *et al*., 2023). Mixed methods have six designs: convergent parallel, explanatory sequential, exploratory sequential, embedding, transformative, and multi-phase (Sharma *et al*., 2023).

Convergent parallel design: This design involves the simultaneous collection of quantitative and qualitative data, the separate analysis of these datasets, and then a comparison evaluation of the results to validate or refute the findings (Sharma *et al*., 2023). It aims to gather complementary data on the research question to gain a deeper understanding of the problem (Sharma *et al*., 2023).

Explanatory sequence design: This strategy entails the researcher initially gathering and analyzing data by a quantitative approach, thereafter employing a qualitative approach to elucidate the preliminary quantitative findings (Nagpal *et al*., 2021).

Exploratory sequential design: This design involves collecting and analyzing qualitative data initially, followed by gathering quantitative data to investigate further and examine the preliminary qualitative findings (Sharma *et al*., 2023).

Embedded design: Embedded designs employ a combination of quantitative and qualitative approaches, with one embedded within the other, to yield greater insight (McLeod, 2024). Embedded design integrates qualitative and quantitative data gathering and analysis at many stages, proving especially beneficial in intervention research. (McLeod, 2024). The embedded design addresses inquiries that require diverse methodologies, enhances an experiment through refined recruitment strategies, scrutinizes the intervention process, and elucidates responses to involvement (Sharma *et al*., 2023).

Transformative mixed methods: This strategy gathers and examines quantitative and qualitative data to comprehensively tackle the research issue (Sharma *et al*., 2023). The concept posits that the research process can be transformational and that the findings may influence the persons or society under investigation (Sharma *et al*., 2023).

Multi-phase mixed design: This design employs both qualitative and quantitative methodologies to collect and analyze data across multiple phases (Sharma *et al*., 2023). The objective is to provide a more comprehensive and precise understanding of the study subject by gathering and analyzing data from both quantitative and qualitative sources across multiple phases (Sharma *et al*., 2023).

4.2.4. Choice of Research Method for this Study

This study employed an exploratory sequential design within a mixed-methods research framework. The study first employed qualitative research to develop the proposed robot-assisted digital storytelling model. The model was then implemented for user evaluation. The user evaluation results were collected and analyzed using a t-test, which falls under the category of experimental quantitative design.

4.3. Design Science Research Paradigm

The four research paradigms deliberated above are general paradigms used in social science and educational projects. The physical sciences and engineering fields share a standard paradigm for conducting research projects. This framework is called the Design Science Research (DSR) Paradigm. DSR is a problem-solving framework that advances human knowledge by creating new artefacts (Vom Brocke *et al*., 2020). Design science research aims to understand how entities can and ought to be formed or organized, typically through human intervention, to achieve a specific set of objectives, referred to as design knowledge (Vom Brocke *et al*., 2020). Sudbury-Riley *et al*. (2020) assert that design science research fulfils two objectives concurrently. It generates scientific information and helps address tangible organizational challenges. Gregorio *et al*. (2021) stated that design science research generates and assesses products to address recognized organizational issues. Numerous process models have been suggested for design science research initiatives. A widely recognized process model for design science research projects was introduced by Peffers *et al*. (2007). According to Peffers *et al.* (2007), the process model consists of six steps: problem identification and motivation, solution objectives, design and development, demonstration, assessment, and communication.

The initial phase of the Peffers design science process (DSP) model involves articulating the study problem and the impetus for addressing the identified issue (Vom Brocke *et al.,* 2020). The second phase of the DSP model establishes the objectives for the proposed solution to the recognized issue (Vom Brocke *et al*., 2020). Step three of the process model sets the stage for designing and creating the artefact (Vom Brocke *et al*., 2020). The fourth element of the DSP model shows how the artefact solves the identified problem. The fourth stage can be carried out using experimentation, simulation, case study, proof, etc., depending on the nature of the artefact (Vom Brocke *et al.*, 2020). Stage five of the DSP model evaluates the extent to which the outcomes of the artefact's implementation align with the established objectives of the solution. Upon assessing the aims against the outcomes, researchers may determine whether to revert to step three for artefact enhancement or to disseminate results (Vom Brocke *et al*., 2020). The sixth aspect of the process model communicates the results of the artefact or the entire project to pertinent stakeholders (Vom Brocke *et al*., 2020). This thesis will employ the DSP model to address the research problem under investigation.

4.3.1. Application of the Design Science Process Model to this study

The research utilizes the DSP model established by Peffers et al. (2007) to direct the study's operations. The phases of the DSP model and the corresponding activities conducted at each phase are as follows:

Problem identification & motivation: A scoping review of robot-assisted digital storytelling and its models conducted by the researcher enabled him to identify the problem. The study identified several robot-assisted digital storytelling research articles and selected a subset based on specific inclusion and exclusion criteria. The chosen research articles were read and analyzed to identify models and other artefacts produced by those articles. This process is referred to as charting in the scoping review. The charting process also identified the interventions in each article and the outcomes of these interventions. At the end of the scoping review, it was discovered that robot storytelling is used in instructional delivery and entertaining audiences. The assessment additionally determined that no robot storytelling paradigm encompasses the following components: requirement analysis, story preparation, robot programming, testing, story presentation, and evaluation. The review concluded that robotic storytelling enhances educational results (Essien & Parbanath, 2024). The gap in the scoping review prompted the researcher to do this study.

Solution objectives: The research project's goals were formulated after identifying the research gap. The primary aim of this study is to develop a robot-assisted digital storytelling model that enhances learner motivation, engagement, and learning outcomes in carbon literacy training through the use of robot-generated storytelling. The study set sub-objectives, which include identifying digital storytelling elements required for the robot-assisted digital storytelling model, evaluating the model's performance, and comparing the robot storytelling training to computer-based digital storytelling.

Design and development: This phase of the process model was used to design and develop the proposed robot-assisted digital storytelling model. The study employed a custom mixed-methods approach, combining content analysis and meta-synthesis, to create the model. The model construction commenced with identifying and retrieving pertinent papers on robot-assisted digital storytelling from three primary electronic databases: Scopus, Web of Science, and Lens. The retrieved documents underwent screening, and the final selections were made based on the inclusion and exclusion criteria. Upon final selection, the content analysis method was utilized to extract actions involved in creating and presenting robot-assisted digital storytelling. After the content analysis, the meta-synthesis method was used to code the extracted activities. Categorical coding of the main activities followed the previous stage, and the proposed model was then framed based on this categorical coding. The following sections provide brief descriptions of the content analysis and meta-synthesis methods employed to develop the proposed model.

Content Analysis: Content analysis is a systematic and reliable method for analysing qualitative data acquired in research, enabling the researcher to make generalizations about relevant categories (Haggarty, 1996). Prasad (2008) defined content analysis as the examination of a message's content, including its meanings, contexts, and purposes. Carley (1990) identifies three primary types of content analysis: conceptual, procedural, and relational content.

Conceptual content analysis focuses on identifying the concepts that are either overtly or implicitly present in the text. A concept is an individual idea, irrespective of its representation by a word or phrase (Carley, 1990). There exist two categories of conceptual content analysis: explicit conceptual analysis and implicit conceptual content analysis. Explicit notions refer to words or phrases present inside the text. Implicit notions refer to words or phrases suggested inside the text (Carley, 1990).

Procedural content analysis focuses on identifying the techniques employed by the author to execute specific tasks (Carley, 1990). It delineates the framework of a particular task and the array of activities available to an individual when undertaking that task. Procedural content analysis enables the researcher to focus on the action and decision sequences presented by the author or text (Carley, 1990).

Relational analysis centres on extracting the mental model implicit in the text (Carley, 1990). Relational content analysis examines both the concepts within a text and the relationships among those concepts (Carley, 1990).

Meta-Synthesis: This is a systematic review method that amalgamates qualitative research findings from distinct studies to produce novel interpretations and enhance a domain of knowledge (McLeod, 2024). Qualitative meta-synthesis is best suited for reinterpreting meaning and developing new theories or explanations of interventions based on findings from multiple high-quality qualitative studies. It is considered original research, utilizing previously published qualitative research as its database (McLeod, 2024). Weinberger (2022) states that the meta-synthesis technique seeks to methodically and reproducibly integrate qualitative findings from multiple investigations. The meta-synthesis methodology encompasses the subsequent procedural steps:

1. Seeking to discover sources, such as publications, for the study.
2. Perform primary analysis to identify documents that align with the research parameters.
3. Coding "within case analysis" to discern the themes or topics that illustrate the principal concepts.
4. Conducting an "across-case analysis" to discern prevalent themes and subjects throughout the diverse papers.
5. Delivering findings in a narrative format.

An expert review was employed to validate the model. Two lecturers with over ten years of experience in the field of lecturing and extensive experience in instructional delivery were contacted to review the process used to develop the model. They were also given questionnaires to respond to the model's validity and suggest any improvements that can be made. The responses from the experts were analyzed, and any suggestions made were responded to.

Demonstration: This phase of the process model demonstrated how the proposed robot-assisted digital storytelling model was utilized to create robot-generated storytelling for delivering carbon literacy lessons. The proposed robot storytelling model has six phases or elements: storytelling requirements, preparation, programming, testing, delivery, and assessment. The first phase was used to select an objective for the storytelling and to select a robot to be used for the storytelling. The second phase was used to prepare the storytelling script and other multimedia. Phase three was used to program the robot with the carbon literacy script. The testing phase was used to test robot programming. The delivery phase provided carbon literacy lessons to a select group of participants. The participants were undergraduate students from Durban University of Technology, South Africa.

Participants: Sixteen students from the Diploma in Software Engineering class were selected to participate in the experiment. Before choosing the students, the entire class was briefed on the research's purpose and the participants' role. Students who decided to partake in the study received informational letters outlining the activities included in the investigation. They were provided consent forms to complete before participating in the study.

The last phase, assessment, was used to assess the learning outcomes of the robot storytelling presentation, which will be discussed in the next phase of the DSP model.

Evaluation: The performance of the proposed robot-assisted digital storytelling model was evaluated after it was used to deliver carbon literacy lessons to selected participants. The assessment was done using tests and questionnaires.

Assessment instruments: The study employed multiple-choice questions to evaluate the carbon literacy knowledge acquired through the robot storytelling lesson delivery. Participants were asked to write two multiple-choice tests: a pre-test and a post-test. Participants were also given questionnaires to assess their satisfaction with the robot storytelling presentation on carbon literacy. The pre-test, post-test, and questionnaires were analyzed using statistical tools.

The results analysis proved that the robot storytelling lesson delivery improved participants' learning outcomes. Participants also enjoyed the robot presentation and were satisfied with the robot-assisted digital storytelling created from the proposed model. Hence, the evaluation's result satisfied the research's aim.

Communication: The research project's results were shared with relevant stakeholders through journal publications and research conferences.

4.4. Research Ethics

Research ethics encompasses the standards and principles delineating acceptable and unacceptable research conduct (ScienceDirect, 2025). According to Arafat (2024), research ethics entails applying moral standards and professional codes of conduct to gather, evaluate, report, and publish data about research participants, especially regarding the participants' rights to confidentiality, privacy, and informed consent. Research ethics encompasses the principles and norms that guide researchers in conducting investigations with integrity, respect for life, and adherence to human rights. Ethical concerns pertain to the intricacies of research ethics, including informed consent, power dynamics, and confidentiality (ScienceDirect, 2025).

4.4.1. Documents for Ethics Clearance.

This study provided the following documents to the DUT-Institutional Research Ethics Committee (DUT-IREC) before obtaining ethics clearance for the proposed experiment (see Appendix F for a copy of the clearance letter).

Letter of information: This study drafted a letter outlining the research's goal and soliciting volunteer involvement. The letter outlined the methods employed during the experiment and the roles of the participants in the investigation. The letter also includes details regarding the communication of study results to participants and other relevant stakeholders. The letter detailed the advantages participants gained from the trial and the hazards or discomforts they faced. Last, the letter explained how participation was kept confidential and anonymous, and participants' responses were kept safe and confidential. The detailed information in the letter of information is found in Appendix A.

Consent form: The study drafted a consent form that allowed the participants to confirm that the researcher adequately informed them of the nature, execution, advantages, and hazards of the study. The form also allowed participants to verify that they had received, read, and understood the informational letter about the study. The consent form allows participants to acknowledge that their information will be processed anonymously in the study report. Participants can confirm on the form that they were given the right to inquire about the study and discontinue participation. The consent form is located in Appendix B.

Gatekeeper's letter: This letter was used to request permission to conduct the experiments at the DUT MICT Seta 4IR Centre of Excellence computer laboratory (see Appendix C)

Data collection tools: DUT-IREC requested copies of the pre-test, post-test, and questionnaires to evaluate the experiment's outcome (see Appendix D for copies of the tools).

TRREE Certification: TRREE stands for Training and Resources in Research Ethics Evaluation. As part of the ethics clearance process, researchers must complete online training in research ethics and evaluation to obtain certification before approval is granted. As a result, the researcher completed the TRREE training (see Appendix E for a copy of the TRREE training certificate).

4.5. Sampling Strategy

Sampling is the process of selecting a sample from a population for research purposes (Bhardwaj, 2019). A sample is a group of people, objects, or items selected from a population to study and gather information (Bhardwaj, 2019). Sampling methods are divided into two groups: probability and nonprobability sampling. In probability sampling, there is a known probability of each member of the population being selected in the sample (Bhardwaj, 2019). Nonprobability sampling is a type of sampling where each member of the population does not have a known probability of being selected in the sample (Bhardwaj, 2019).

Each of the two groups of sampling mentioned above has its types. The following are the types of probability sampling: simple random sampling, stratified random sampling, systematic sampling, cluster sampling, and multistage sampling (Bhardwaj, 2019). Also, purpose sampling, convenience sampling, snowball sampling, and quota sampling are types of nonprobability sampling (Bhardwaj, 2019).

This study employed convenience sampling to select participants for the study experiment. In convenience sampling, the researcher utilizes a sample that is readily available and accessible (Golzar *et al*., 2022). For a researcher to employ a convenience sample implies that the researcher's primary concern is the availability of the participants (Golzar *et al*., 2022). Due to this motive, the study selected a sample from the Advanced Diploma in Software Engineering class at the Durban University of Technology, South

Africa. The sample size consisted of 16 individuals, comprising 10 males and six females, all within the 20- to 30-year age range.

4.6. Participants Recruitment

The researcher visited the Diploma in Software Engineering class at the Durban University of Technology, and after obtaining permission from the lecturer, the class was briefed on the research’s purpose and the participants' roles. The researcher rescheduled a meeting with the students to select those who were willing to participate in the experiment. Students who decided to participate in the study received informational letters outlining the activities included in the investigation, as required by the ethics committee. The researcher informed the selected participants of the date for the experiment. On the day of the experiment, the participants were provided consent forms to complete before participating in the study. Sixteen students from the Diploma in Software Engineering class opted to participate in the experiment.

CHAPTER FIVE

Robot-Assisted Digital Storytelling Model for Carbon Literacy Training

This chapter presents the method used to develop the proposed robot-assisted digital storytelling model, along with an expert review of the model.

5.1. Introduction

The proposed robot storytelling model is synonymous with an instructional design model. The reason for the assertion is that the model was used to prepare robot storytelling and deliver carbon literacy training to selected participants. Training is a type of teaching. Lee and Jang (2014) assert that an instructional design model serves as a conceptual framework that aids instructional designers in comprehending pertinent variables, functioning as an operational or procedural instrument that directs designers throughout the design process. This instructional design model guides instructors in planning, analyzing, presenting, and evaluating teaching and learning activities. The instructional design model also guides instructors in selecting teaching and learning materials and the curricula for teaching. Taylor (2004) characterized instructional design as a methodical creation of instructional specifications that employ learning and instructional theory to guarantee instructional quality. Bajracharya (2019) defines instructional design as a systematic process for the sequential and authentic development of educational or training programs, curricula, or courses. This chapter presents the activities of developing the proposed robot-assisted digital storytelling model for carbon literacy training.

According to Lee and Hong (2024), instructional model research is developed in three stages: model development, validation, and use. Lee and Hong (2024) asserted that the model development process may utilize literature analysis, field observation, and the insights of prior designers or developers. This model drew on the experiences of earlier developers of robot storytelling instruction to inform the proposed model. The study went through model development, expert review, and user-based evaluation. However, the user-based evaluation stage is discussed in the next chapter.

5.2. Model development

The proposed model was developed by analyzing literature on robot storytelling systems developed by researchers and instructors in the educational sector. Analyzing selected articles on robot storytelling enabled the study to identify strategies, methods, and activities used in robot storytelling instructional delivery to achieve set objectives. The model development follows the stages: identification of relevant studies and sources, screening and selecting articles, extraction of robot storytelling activities, coding of extracted activities, categorical coding of primary activities, and framing of the model.

Identification of relevant studies and sources used: Records were examined and obtained from three electronic databases: Scopus, Web of Science (WoS), and Lens. The search duration was from January 10, 2024, until March 10, 2024. The records under examination included primary research that met the search criteria, either published in English or translated into English. The search terms were applied to title fields across all three databases, for example, using phrases such as "Title (robot storytelling)," "Title (robot digital storytelling)," "Title (robot-assisted storytelling)," or "Title (robot-based storytelling)." Following the initial search on January 10, 2024, alerts were set up in the three databases to identify relevant publications for this study. A typical search term in the Scopus database is as follows: TITLE (robot AND storytelling) OR TITLE ("robot-assisted storytelling") OR TITLE ("robot-based storytelling") OR TITLE (robot "digital storytelling"). The literature or records for the study were chosen according to the inclusion and exclusion criteria outlined in Table 5.1.

Table 5.1: Inclusion and Exclusion Criteria

	Inclusion criteria
1	Literature published in the English language
2	The selected period from 10/01/2004 to 10/03/2024

3	Primary research focused on robot storytelling.
4	Qualitative studies
5	Articles and conference papers
6	Subject areas include robotics, computer science, and education.
	Exclusion criteria
1	Literature concentrating on alternative robotic research devoid of storytelling.
2	Research published in other languages
3	Book chapters
4	Quantitative studies

Screening and selection of articles: 142 records were acquired from the Lens database, whilst 72 were sourced from the Scopus database. Additionally, 21 entries were acquired from the WoS Database. All records were obtained from January 10, 2024, to March 10, 2024. A total of 235 records were obtained. The records from the three databases in BibTeX format were imported into Mendeley Reference Manager (Elston, 2019) for consolidation into a single library. The consolidated library was exported to EndNote (Gotschall, 2021). Endnote eliminated duplicate entries, resulting in 76 records. The next phase was screening. The titles and abstracts of the remaining records were examined individually to choose the final records. The screening criteria encompass all robot storytelling records administered to selected individuals. Following the screening, 20 records were chosen for the study. Figure 5.1 illustrates the PRISMA flow diagram for the selection procedure.

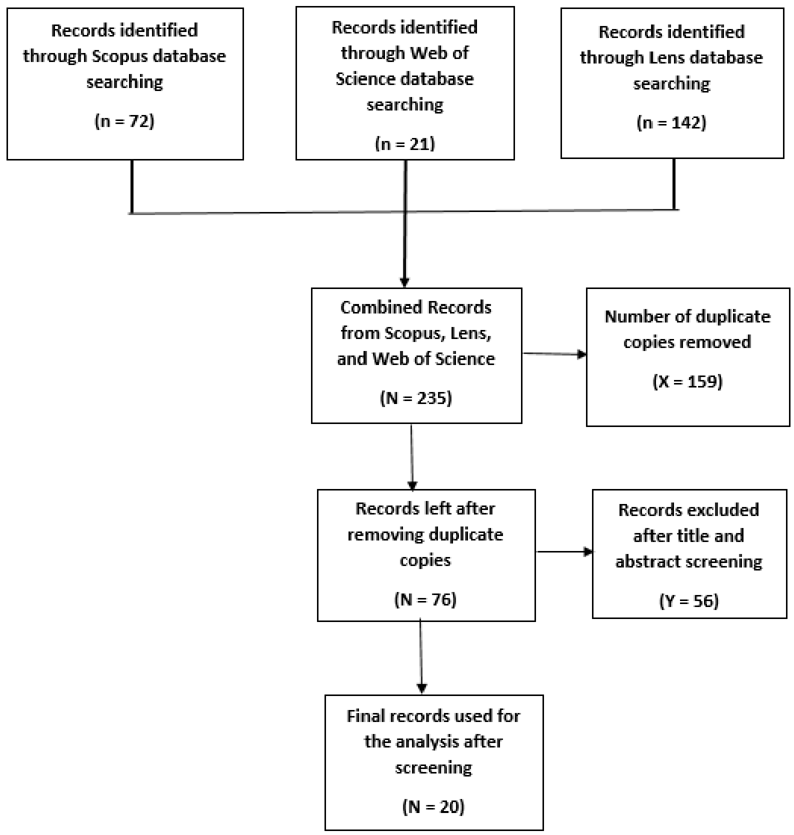

Figure 5.1: PRISMA flow diagram

Extraction of robot storytelling instructional activities in the selected articles: This section employed content analysis to extract activities carried out in robot storytelling instructional delivery from the selected articles. Content analysis is a systematic method used to examine the informational substance of textual material (Forman & Damschroder, 2007). Each article was read carefully, and the activities carried out in creating robot storytelling instructions were identified. The content analysis also identified storytelling presentations and evaluation activities. Table 5.2 shows the extracted data from the selected articles. The articles were assigned serial numbers, which were used to represent them in Table 5.3, thereby reducing the size of the coding table.

Table 5.2: Content analysis of selected robot storytelling instruction.

Assigned letter	Author(s) (year)	Title of Article	Instructional activities
1	Fridin (2014)	"Storytelling by a kindergarten social assistive robot: A tool for constructive learning in preschool education" (Fridin, 2014)	• Selection of a robot and video cameras • Selection of storytelling audience. • Information and letters of consent were given to the children's parents, who also signed on behalf of their children. • The story title was selected. • The room for storytelling was selected. • Identification of relevant knowledge of the target audience • Installation of the robot's application • The storytelling code was written. • Programming code is uploaded into the robot. • Testing of the robot storytelling system before final story presentation • Robot story presentation. • Oral assessment of robot storytelling.

2	Chang *et al*. (2023)	"Fostering professional trainers with robot-based digital storytelling: A brainstorming, selection, forming and evaluation model for training guidance" (Chang *et al.*, 2023)	• Selection of a robot for storytelling • Participants were selected to create a robot storytelling system. • A pre-test was conducted to assess initial knowledge. • Introduction of learning purpose and task • Design of system architecture • Preparation of lesson content/script. • The robot was programmed with story content • The robot was programmed with gestures • The robot presented a lesson. • A post-test was conducted. • Interviews were also used to evaluate the storytelling activities.
3	Liang and Hwang (2023)	"A robot-based digital storytelling approach to enhancing EFL learners' multimodal storytelling ability and narrative engagement" (Liang & Hwang, 2023)	• Selection of a robot for storytelling • Participants were selected to create a robot storytelling system. • Collection of images and other multimedia

			• Reading of story text. • Composition of story script and storyboard • Recording dialogue and narration. • Design of the question. • A robot programmed with the story. • Robot storytelling was tested before the final presentation. • Robot story presentation. • Storytelling was evaluated using an oral assessment.
4	Leite *et al*. (2015)	"Emotional Storytelling in the Classroom: Individual versus Group Interaction between Children and Robots" (Leite *et al.,* 2015)	• A robot for storytelling was selected. • Storytelling audiences were selected. • Audiences were made to sign consent forms. • The purpose of the study was selected and introduced to audiences. • The system architecture was designed. • A story script was developed. • Robot behaviours/gestures were programmed.

			• The robot was programmed to interact with the audience. • The robot story was presented interactively. • Storytelling was evaluated using interviews.
5	Conti *et al.* (2017)	"A Comparison of Kindergarten Storytelling by Human and Humanoid Robots with Different Social Behavior" (Conti *et al*., 2017)	• Selection of storytelling audience • Identification of relevant knowledge of the audience • The parent signed consent forms for their children (the audience). • Selection of a robot. • Selection of story title • A story text of 900 words was prepared, • Codes of gestures were also programmed. • The robot was programmed to tell the story. • Testing of the robot presentation was done. • The robot story was presented. • Written assessment of storytelling.
6	Ligthart *et al*. (2020)	"Design Patterns for an Interactive Storytelling	• A robot, sound recorder, and laptop computer were

		Robot to Support Children's Engagement and Agency" (Ligthart *et al.*, 2020)	selected to facilitate the development of storytelling. • Participants were selected to create a robot storytelling system. • Storytelling audiences were selected. • Guardians sign consent forms for their children (audiences). • A group of children created a story text. • The robot was programmed with the story. • The robot storytelling was tested using schoolchildren and further improved. • A room for storytelling was set up. • The robot presented the story. • Robot storytelling was evaluated using interviews.
7	Appel *et al*. (2021)	"The emotional robotic storyteller: On the influence of affect congruency on narrative transportation, robot perception, and	• A robot was selected. • The story text was prepared. • Storytelling audiences were selected. • Audiences were made to sign consent forms.

		persuasion" (Appel *et al*., 2021)	• The robot was programmed to tell a story. • The robot was also programmed to display different emotional behaviors and gestures. • The robot presented the story. • A written questionnaire was used to evaluate the robot's storytelling.
8	Park *et al.* (2017)	"Telling Stories to Robots: The Effect of Backchanneling on a Child's Storytelling" (Park *et al*., 2017)	• A robot for storytelling was selected. • Storytelling participants were selected, • The story was discussed. • The system architecture was designed, • Images were prepared. • Robots were programmed to respond to storytelling with facial and body expressions/gestures. • The robot responded to children through a storytelling presentation. • Storytelling was evaluated using questionnaires.
9	Ham *et al.* (2015)	"Combining Robotic Persuasive Strategies:	• The storytelling audiences were selected.

		The Persuasive Power of a Storytelling Robot that Uses Gazing and Gestures" (Ham *et al.,* 2015)	• The title of the story was selected. • A robot was selected. • The purpose of storytelling was explained to audiences. • A professional actor was asked to act and tell the story, and the narration (with gestures and gazing) was recorded via video. • A story script was prepared. • The actor's gestures and gazing were programmed into the robot. • The robot storytelling was tested and evaluated before final delivery to the intended audience. • The robot presented the story. • A questionnaire was used to evaluate the effectiveness of robot storytelling.
10	Chen Hsieh and Lee (2023)	"Digital storytelling outcomes, emotions, grit, and perceptions among EFL middle school	• Participants were selected to create a robot storytelling system.

		learners: robot-assisted versus PowerPoint-assisted presentations" (Chen Hsieh & Lee, 2023)	• Participants' needs assessments were measured. • The robot was selected. • Picture book and image were selected. • The story title was also selected. • The story text was prepared. • The voice was recorded. • The storyline was prepared. • The images, audio, and text were programmed into the robot. • Robot storytelling was tested. • The robot presented a story to the audience. • Storytelling was evaluated using questionnaires.
11	Chang *et al*. (2023)	"Effects of Robot-assisted Digital Storytelling on Hospitalized Children's Communication during the COVID-19 Pandemic" (Chang *et al*., 2023)	• A robot was selected • The story title was chosen. • Story audiences were selected. • The audience's parents signed consent forms. • The purpose of storytelling was selected.

			• The story plot was prepared. • A video was prepared. • The robot was programmed to tell a story and interact with the audience. • The robot presented a story to the audience. • The story was evaluated using questionnaires.
12	Kory Westlund *et al* (2017)	"Flat vs. Expressive Storytelling: Young Children's Learning and Retention of a Social Robot's Narrative" (Kory Westlund *et al*., 2017)	• Storytelling audiences were selected. • Audiences' relevant knowledge was identified. • Parents in the audience signed consent forms on behalf of their children. • The aim and objectives of the storytelling were selected. • A robot for storytelling was selected. • A tablet was used to display a storybook. • The robot was programmed with the story. • The robot storytelling system was tested. • The robot presented the story to the audience.

			• An oral test was administered to the audience.
13	Ham *et al.* (2011)	"Making Robots Persuasive: The Influence of Combining Persuasive Strategies (Gazing and Gestures) by a Storytelling Robot on Its Persuasive Power" (Ham *et al*., 2011)	• Selection of a robot. • The storytelling audience was selected. • The story title was chosen. • Recording video. • Installation of robot application (Choregraphe) • The story script was created. • The robot was programmed to tell a story • Robot storytelling was tested. • The robot presented a story to the audience. • Questionnaires were given to the audience to evaluate storytelling.
14	Tokunaga *et al* (2019)	"Cognitive Training for Older Adults with a Dialogue-Based, Robot-Facilitated Storytelling System" (Tokunaga *et al*., 2019)	• The storytelling audience was selected. • A robot was also selected. • Thirty-six stories told by adults were recorded, and the stories to be told were extracted from the recorded stories.

			• Questions and answers were prepared. • Grammatical, syntactic, and formatting errors were also checked. • The robot was programmed to tell a story. • The robot presented the story to the audience. • Questionnaires were used to evaluate the storytelling.
15	Tamura *et al*. (2018)	“Investigation of the Impression of Storytelling with Robots on Multiple Children” (Tamura *et al*., 2018)	• The robot for the storytelling was selected. • The story title was chosen. • Storytelling audiences were selected. • The purpose of storytelling was selected and explained. • A room for storytelling was prepared, • A picture book was selected. • A story text was prepared. • The two robots were programmed with the story text. • Gazing was programmed into the robot.

			• Robots presented their stories. • Evaluation of storytelling was carried out using interviews • Questionnaires were also used to evaluate the story.
16	Wu *et al.* (2017)	"Investigation of the Roles of Humans and Robots in Collaborative Storytelling" (Wu *et al.*, 2017)	• The storytelling audience was selected. • A robot was selected for the storytelling. • The story title was selected. • A robot application (Choregraphe) was installed. • The story script was prepared. • The robot was programmed using Choregraphe. • The robot was programmed to recognize gestures and maintain eye contact with its users. • Robot gestures were tested. • The robot presented a story in collaboration with the children and later presented alone.

			• Multiple-choice questions were used to evaluate the storytelling.
17	Shen and Lin (2018)	“Robot-assisted Reading: A Preliminary Study on the Robotic Storytelling Service to Children in the Library” (Shen & Lin, 2018)	• The story title was chosen. • A robot for storytelling was selected. • Storytelling audiences were selected. • The story voice/audio file was selected. • A story text file was prepared. • The robot was programmed with the story, • The robot was programmed with gestures and facial expressions. • The robot presented a story to the audience. • Robot storytelling was evaluated using questionnaires that were interpreted orally.
18	Hu *et al*. (2022)	“The effects of constructing robot-based storytelling system on college students' computational thinking	• Participants were selected to create a robot storytelling system. • A robot for storytelling was selected. • Participants' technology comprehension/knowledge

		skill and technology comprehension” (Hu *et al.*, 2022)	was verified using a pre-test. • A story script was developed. • Storybook and multimedia elements collected. • Robot storytelling application/editor installed on a computer. • The robot was programmed using the robot storytelling editor. • The storytelling system was tested. • The entire activity of creating robot storytelling was evaluated using a multiple-choice test.
19	Chen Hsieh (2021)	“Digital Storytelling Outcomes and Emotional Experience among Middle School EFL Learners: Robot-Assisted versus PowerPoint-Assisted Mode” (Chen Hsieh, 2021)	• Participants were selected to create a robot storytelling system. • The robot for storytelling was selected. • The story title was selected. • The participants' relevant knowledge was determined using pre-tests. • Picture books and Images were collected.

			• Images were programmed into the robot. • The robot was programmed to show gestures. • Storytelling was tested. • The robot presented a story to the audience. • Storytelling was evaluated using questionnaires. • An interview was also used to evaluate the story.
20	Bravo *et al.* (2021)	"Using Robots with Storytelling and Drama Activities in Science Education" (Bravo *et al.*, 2021)	• Participants were selected to create a robot storytelling system. • The robot to be used for the storytelling was selected, • The aim and objectives of the storytelling were selected. • The story was narrated to serve as a guide for creating a script. • The script was developed. • The robot was programmed to tell a story. • The robot storytelling system was tested and rehearsed before the final presentation.

			• The robot presented the story to the audience. • Storytelling was evaluated using questionnaires.

Coding of extracted activities: This section of the model development process coded the activities extracted in the previous section under selected headings (see Table 5.3). The headings represent the activities extracted in Table 5.2. The coding put the same or similar activities in the chosen articles under the same column. The motive of the coding is to ensure every activity extracted in Table 5.2 is placed under one column in Table 5.3. When done, it implies that the column headings in Table 5.3 summarize the activities extracted in Table 5.2. The article serial numbers in Table 5.3 represent the articles in Table 5.2, and the symbol # shows the activities under the headings of the respective articles.

Table 5.3: Coded instructional activities extracted in the content analysis stage.

Article serial number	Robot Storytelling Instructional Activities																								
	Selection of robots and other hardware devices	Selection of participants to create storytelling	Discussion, reading, and writing of story text	A needs/knowledge assessment was conducted	Selection story title	Selection of storytelling audience	Letter of information and consent forms signed	Purpose and objectives of storytelling	Prepare story plot/storyline	Recording of story audio, video, and narration	Storybook, picture book, images, or multimedia selection	Preparation of story script	Checking grammar, syntax, and other errors	Preparation of storyboard	Design storytelling architecture	Installation of the robot application	Preparation of questions and answers	Writing of storytelling code	Program / upload storytelling code into the robot	Program a robot with gestures, emotion, and gazing	Testing of the robot storytelling system	Preparation of the room for storytelling	The robot presented the story to the audience	Written assessment	Oral assessment
1	#			#	#	#	#									#		#	#		#	#	#		#
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5	#		#	#	#	#	#												#	#	#		#	#	
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Categorical coding of main activities: This section categorizes the main activities as obtained in Table 5.3. The column headings and subheadings in Table 5.4 describe robot storytelling creation and presentation activities. The synthesis is based on the author's experience in robot storytelling and the method proposed by Tracey and Richey (2007). Activities in the same procedure stage used to create and present a robot storytelling system, as described in the selected articles, were grouped in the same column. For example, activities such as choosing a story title, determining the purpose and objectives of storytelling, and selecting the robot and other hardware used for storytelling took place at the beginning of the storytelling creation process. Therefore, these activities were listed in the same column as the column heading 'storytelling requirements'. The column headings in Table 5.4 were used to frame the proposed model. The symbol (√) in Table 5.4 indicates the column heading where the activities fall.

Table 5.4: Categorical coding of primary activities.

Main activities	Categories of activities					
	Storytelling requirements	Preparation	Programming	Testing	Delivery	Assessment
	Robot storytelling requirements	Preparation of robot storytelling materials	Programming the robot with the story	Testing the robot storytelling system	The robot delivers storytelling instructions to audiences	Assessing the outcome of the robot storytelling instruction
Oral assessment						√
Written assessment						√
The robot presented the story to the audience.					√	
Preparation of the room for storytelling					√	
Testing of the robot storytelling system				√		
Program a robot with gestures,			√			

behaviour, and gazing						
Program / upload storytelling code into the robot			√			
Writing of storytelling code			√			
Preparation of questions and answers		√				
Installation of the robot application			√			
Design storytelling architecture		√				
Preparation of storyboard		√				
Checking grammar, syntax, and other errors		√				
Preparation of story script		√				

Storybook, picture book, images, or multimedia selection		√				
Recording of story audio, video, and narration		√				
Prepare story plot/storyline.		√				
Purpose and objectives of storytelling	√					
Letter of information and consent forms signed					√	
Selection of storytelling audience					√	
Selection of story title	√					
A needs/knowledge assessment was conducted.					√	

Discussion, reading, and writing of story text		√				
Selection of participants to create storytelling	√					
Selection of robots and other hardware devices	√					

Framing the model: In the previous section, one or two keywords were used to represent the column headings and describe the activities. These keywords were used to frame the proposed model, as shown in Figure 5.2. In terms of modeling, the keywords are referred to as elements of the model. The proposed model begins with storytelling requirements, followed by preparation, programming, testing, delivery, and assessment. The following are brief descriptions of the model's elements. The descriptions are based on the activities for each component in Table 5.4.

Storytelling requirement: The storytelling requirement is the first phase of the proposed model for robot storytelling instruction. This phase recommends that robot storytelling development begins with the selection of a topic for the story and the establishment of its purpose and objectives. When the instructor wants to involve learners in creating the storytelling system, participants are recruited in this phase. In this phase, robots and other hardware devices, such as cameras and recorders, will be selected to develop the storytelling system.

Preparation: The preparation phase follows the storytelling requirement. This phase is used to record narration, video, and audio to prepare the storytelling. In this phase, picture books and storybooks are used to guide the development of the story. Images are also collected in this phase. In this phase, the story text, script, storyline, plot, and storyboard are prepared. Questions and answers that will be used to program the selected robot are also prepared in this phase. In this phase, the grammar, syntax, and formatting of the story text are checked. The architecture of the storytelling system is also designed in this phase to guide the development of the robot storytelling system.

Programming: Programming is the third phase of the model. In this phase, developers install the robot application to create the storytelling system. They write the storytelling code. This phase also involves developing gestures, behaviors, and gaze code or a robot's configuration to display different behaviors during storytelling. Depending on the robot's features, this phase uploads multimedia elements such as text, audio, images, and video into the robot.

Testing: Testing is the fourth phase of the proposed model. The developers use this phase to test the robot's presentation. The speed at which the robot speaks and the clarity of the presentation are checked during testing. Robot gestures and gaze are also checked to ensure they are convenient for the audience. In case of any error in the robot's presentation, the developers should amend the robot's code to correct the mistake.

Delivery: The fifth phase of the model is delivery. This phase is used to prepare a room for storytelling. The target audience should be selected, and letters of information detailing the purpose of the storytelling and the presentation procedure should be provided to them. This information can also be presented orally to the audience. After that, consent forms are given to audiences or their parents to sign, depending on the audience's age level. After the consent forms are signed, the audience is seated. In this phase, the needs assessment or relevant prior knowledge of the audience is measured, and the robot then begins the story presentation.

Assessment: Assessment is the last phase of the model. This phase evaluates robot storytelling instruction. Written assessments, such as multiple-choice questions, can be used to determine knowledge acquisition, and questionnaires can be employed to assess satisfaction with the robot's storytelling instruction delivery. Oral assessments, such as interviews, can also be used to evaluate the effectiveness of robot storytelling instruction. The choice of a particular instrument to assess robot storytelling instruction depends on the instructor's discretion and the age group of the audience.

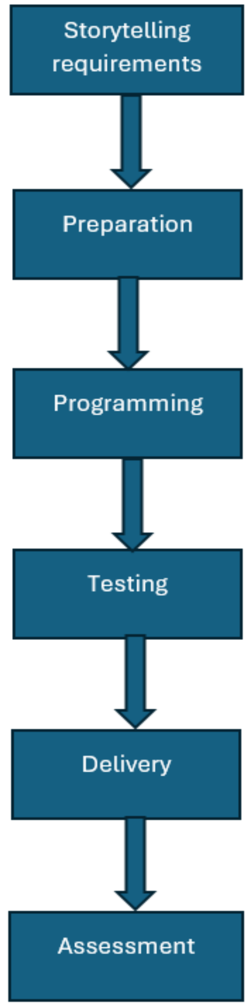

Figure 5.2. The proposed model for robot-assisted digital storytelling training/instruction

Activities to be carried out under each phase of the proposed model may also depend on the topic of the robot storytelling instruction and features of the selected robot. Some robots have screens to display images and videos, while others do not. Before proceeding with the activities for robot storytelling, you must first select the topic of instruction and the robot that will deliver it. The developer should also be aware of which activities in the model can be applied to the intended robot storytelling lesson.

5.3. Expert review of the model

The first part of the model validation is the expert review. Two experts were contacted to review the entire process of designing the robot-assisted digital storytelling instructional model. The experts were selected based on their expertise in Information Technology instructional delivery. The model development process was explained to them, and they were provided with the model document to review and respond to the questionnaire (see Appendix G). They were also asked to make recommendations for improving the model. The questionnaire was constructed utilizing 5-point Likert scale items. Likert items measure respondents' opinions on a particular question or statement. Ultimately, the reviewers provided suggestions for improving the model. The corrections were carried out and resubmitted to them for final review. Table 5.5 contains the coded responses of the two reviewers. The responses were coded using the following keys to analyze the data.

- Strongly disagree → 1
- Disagree → 2
- Neutral → 3
- Agree → 4
- Strongly agree → 5

Table 5.5: Coded table from experts' responses

S/N	Statement	Reviewer A	Reviewer B	Mean mark = $\frac{X_1 + X_2}{2}$
		Marks allocated (X_1)	Marks allocated (X_2)	
1	The elements or phases of the model are adequate for instruction delivery	4	4	4
2	All elements or phases are relevant to robot storytelling creation.	5	4	4.5
3	The meaning of the model elements is apparent.	5	4	4.5

4	The method used to develop the instructional model is appropriate.	5	5	5
5	The method carried out by the researcher justifies the phases or elements of the instructional model.	5	4	4.5

According to Table 5.5, both reviewers A and B agreed that the model's elements are adequate for creating robot storytelling instruction. One of the two reviewers strongly agreed that all the model elements are relevant to robot storytelling creation, while the other agreed. Concerning the meaning of the elements, one of the two reviewers strongly agreed that the meaning of the elements is apparent, while the other agreed. In addition, the two reviewers strongly agreed that the process used to develop the model was appropriate. Finally, reviewer A strongly agreed that the method used in creating the model justifies the elements of the model, while reviewer B agreed. From the comments provided by the reviewers, the model is simplified and contains all the necessary elements required to create robot storytelling.

5.4. Summary

Twenty robot storytelling research articles were selected, and the content analysis method was used to extract the procedures and activities used by the researchers to create robot storytelling. The procedures and activities were coded under selected headings. The headings for the coding were also categorized, and based on the categories, the model was framed. The model document and questionnaires were presented to two experts for review, and their responses were processed.

CHAPTER SIX

Model Experimentation, Results, and Discussion

The previous chapter discussed the method used to develop the robot-assisted digital storytelling model, followed by an expert review of the model. This chapter addresses the execution and user-based assessment of the proposed model.

6.1. Introduction

The proposed model was utilized to develop robot-assisted digital storytelling, which delivered carbon literacy instructions to selected undergraduate students, aiming to enhance their knowledge of carbon literacy. A narrated PowerPoint presentation on carbon literacy was also prepared and presented to a select group of students. The study employed a pre-test and post-test design, comparing the results to determine if robot storytelling and narrated PowerPoint presentations enhanced students' understanding of carbon literacy. The study also compared the post-test of the robot storytelling to that of the narrated PowerPoint presentation.

An experimental design was employed to implement the model and deliver instruction on carbon literacy to a select group of students. According to Creswell (2015), experimental research is a study that assesses a theory, method, or procedure to determine its effect on the result or dependent variable. Experimental research compares two or more groups on one or more measures (Ramadhana & Allo, 2021).

6.2. Participants

The participants were selected from an advanced diploma program in software engineering class at the Durban University of Technology, South Africa. Sixteen students opted to engage in the study after the class was briefed on the study's purpose. The individuals involved were in the twenty-to-thirty age range, consisting of ten males and six females. The chosen students were randomly allocated to the experimental and control groups. The experimental group was instructed via robot-assisted digital storytelling, whereas the control group was taught through a narrated PowerPoint presentation.

6.3. Design and delivery of robot-assisted digital storytelling

The experiment followed the proposed model developed in the previous chapter to design and deliver robot-assisted digital storytelling. The proposed model has six elements: storytelling requirements, preparation, programming, testing, delivery, and assessment (see Figure 6.1). The following is a brief discussion of the activities undertaken at each phase of the model.

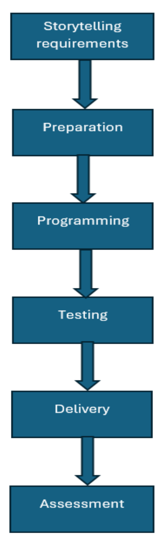

Figure 6.1: The proposed model for robot-assisted digital storytelling instruction/training

Storytelling requirements: In this phase of the robot storytelling instruction, the study selected the topic of carbon literacy and chose the Nao robot to deliver the lesson. The Nao robot is a humanoid robot developed by Aldebaran Robotics (Shamsuddin *et al*., 2011). Nao possesses 25 degrees of freedom and is capable of bipedal locomotion (Deutsch *et al*., 2011). One of its processors is situated in its breast, capable of reading all sensors within an 8-millisecond cycle period (Deutsch *et al*., 2011). Nao robot has its central processing unit in its head, which runs on the Gentoo Linux operating system (Deutsch *et al*., 2011). Nao has a height of 57.3 cm, a width of 27.3 cm, and a weight of 5.6 kg. Nao's body is made of plastic and features a 21.6V 2Ah lithium-ion battery, providing a usage duration of 90 minutes (Seo & Robotics, 2013). Nao may connect to a computer with either a cable or a wireless connection. Choregraphe is an intuitive graphical user interface programming package utilized to develop apps that govern Nao's functionalities. Nao has four directional microphones, two speakers, and two cameras. The study used both the Nao robot and a laptop with internet connectivity.

Preparation: In this phase of creating the robot storytelling instruction, the study typed carbon literacy text to program the robot and checked the text for grammatical errors. The study also designed a robot storytelling system architecture to guide the development of the storytelling system (see Figure 6.2). The system architecture describes the components of a system and their intercommunication (Luckham *et al.,* 1995). The following are brief descriptions of the elements of the storytelling system architecture.

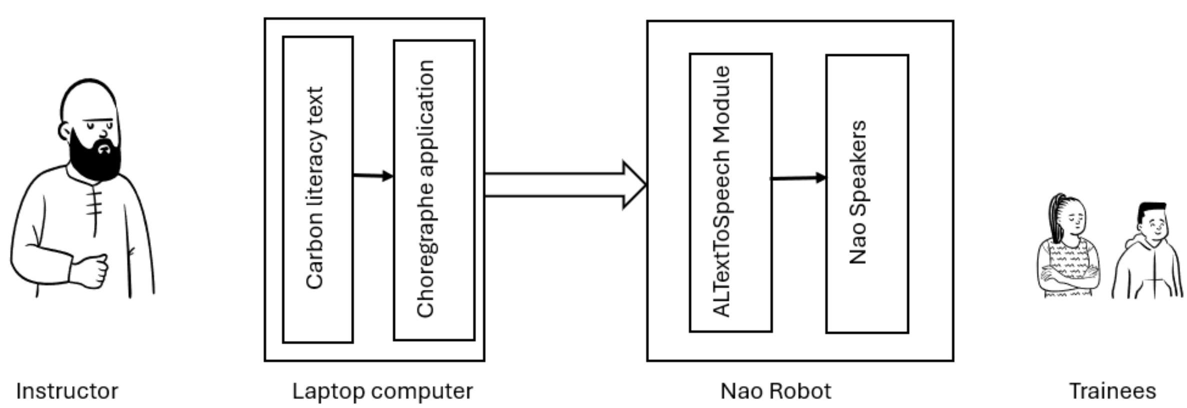

Figure 6.2: Architecture of robot-assisted digital storytelling system

Choregraphe: Choregraphe is the Nao robot's application for programming its modules. It lets users upload datasets and program code into the robot's memory. Choregraphe is a very intuitive graphical environment that allows Nao to be programmed (Pot *et al*., 2009).

ALTextToSpeech: The ALTextToSpeech module enables the robot to vocalize (Rikasofiadewi and Prihatmanto, 2016). It transmits commands to a text-to-speech engine and facilitates voice customization (Rikasofiadewi and Prihatmanto, 2016). The synthesis outcome is transmitted to the robot's loudspeakers (Rikasofiadewi and Prihatmanto, 2016). Nao has two stereo loudspeakers for text-to-speech synthesis, one in the right ear and one in the left ear (Rikasofiadewi and Prihatmanto, 2016). The speakers and microphone operate within a 20-20,000 Hz frequency range. Nao utilizes the Acapela text-to-speech (TTS) engine, developed by Acapela Group, for synthesizing audio output. (Rikasofiadewi & Prihatmanto, 2016).

Nao Speakers: The processed carbon literacy data is sent to the robot's speakers for playback. Nao offers two loudspeakers and four microphones. The speakers' output voice is used for speaking, and the microphones are used for listening (Pot *et al*., 2009).

Programming: In this phase, the study installed the Choregraphe application on a laptop computer and used it to write the coding box diagram in Figure 6.3.

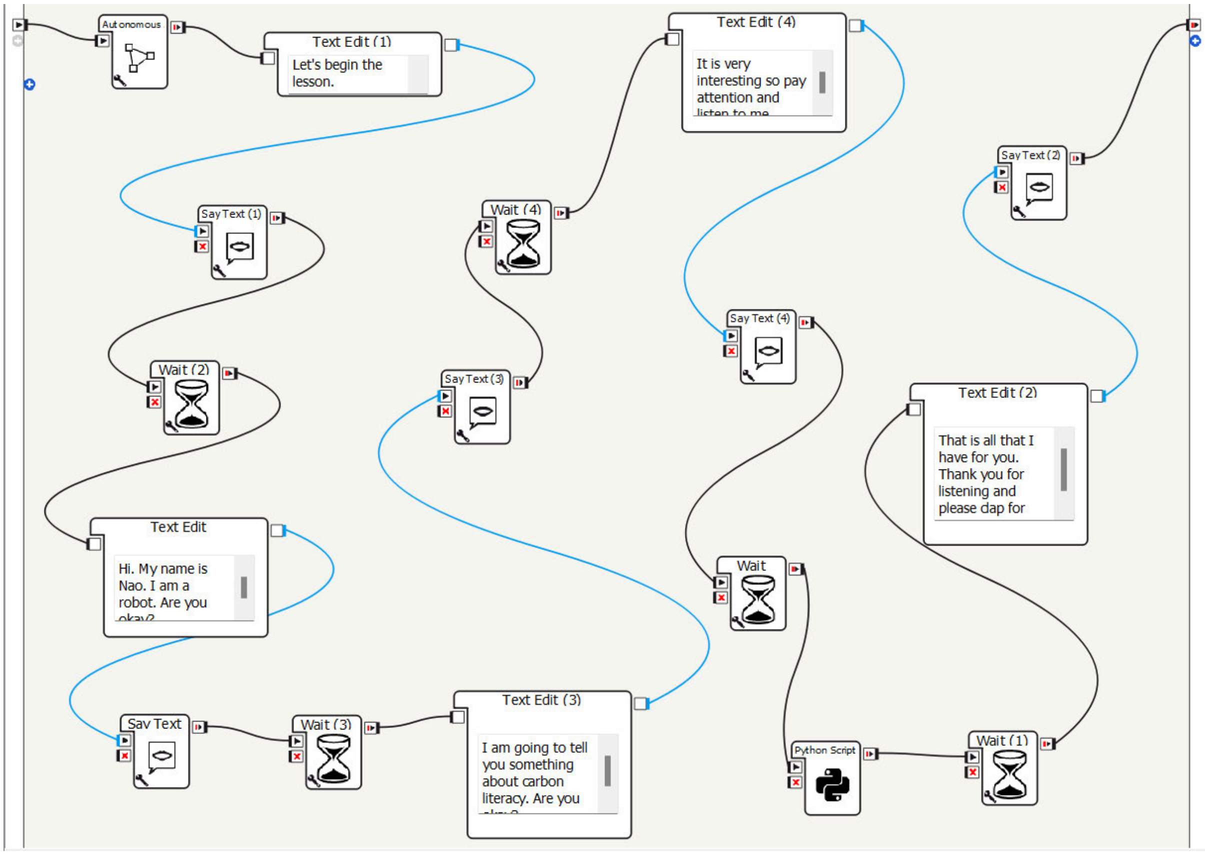

Figure 6.3: Coding box diagram of Nao Robot on carbon literacy instruction (Pot et al., 2009)

The coding box diagram in Figure 6.3 consists of one autonomous box, five Text edit boxes, five Say text boxes, five Wait boxes, and one Python script box. The following are brief descriptions of these coding boxes.

Autonomous box: This box activates autonomous life through blinking, background movement, awareness, listening, and speaking movements. By default, all these autonomous abilities are enabled. This box is used to deactivate some or all of the autonomous skills (Anter *et al.*, 2019). The following is the Python code for the autonomous life box.

```
class MyClass(GeneratedClass):

    def __init__(self):

        GeneratedClass.__init__(self, False)
```

```
    def onLoad(self):
        self.autonomouslife = self.session().service("ALAutonomousLife")
    def onUnload(self):
        pass
    def onInput_onStart(self):
        self.enableAnAbility("AutonomousBlinking")
        self.enableAnAbility("BackgroundMovement")
        self.enableAnAbility("BasicAwareness")
        self.enableAnAbility("ListeningMovement")
        self.enableAnAbility("SpeakingMovement")
        self.onDone() # activate output of the box
    def enableAnAbility(self, name):
        self.autonomouslife.setAutonomousAbilityEnabled(name,
        self.getParameter(name))
```

Text edit box: This box is used to process text. It is connected to the Say text or animated Say box, enabling Nao to speak the text in the Text edit box (Anter *et al*., 2019). The following is the Python code for one of the Text edit boxes, which allows Nao to say, "Hi. My name is Nao. I am a robot. Are you okay?"

```
class MyClass(GeneratedClass):
    def __init__(self):
        GeneratedClass.__init__(self)

    def onInput_onStart(self):
        self.onStopped("Hi. My name is Nao. I am a robot. Are you okay?")
```

Say text box: This box enables Nao to say text. It is connected to the Text edit box to allow Nao to speak the text entered into the text edit box. This box also changes the speed at which Nao speaks (Anter *et al.,* 2019).

Wait box: This box delays Nao's activity for a specified period before proceeding to the next activity. By default, this box is configured with a delay time of one second (Anter *et al.*, 2019).

Python script box: This box inserts Python code for Nao's program (Anter *et al.,* 2019). The study utilized the Python script box to develop the main carbon literacy instructional code. The following is the Python code for the carbon literacy instruction.

```
class MyClass(GeneratedClass):

    def __init__(self):

        GeneratedClass.__init__(self)

    def onLoad(self):

        #put initialization code here

        pass

    def onUnload(self):

        #put clean-up code here

        pass

    def onInput_onStart(self):

        #self.onStopped() #activate the output of the box

        #Preparations

        import time

        tts = ALProxy("ALTextToSpeech")

        tts.setParameter("speed", 70)
```

```
tts.say("Carbon literacy is an awareness of the carbon dioxide costs and
impacts of everyday activities.")

time.sleep(3)

tts.say("Carbon literacy also involves the ability and motivation of
everyone to reduce the emission of greenhouse gases.")

time.sleep(3)

tts.say("Greenhouse gases are gases in the earth's atmosphere that trap
heat and increase the earth's temperature.")

time.sleep(3)

tts.say("This phenomenon is called global warming.")

time.sleep(3)

tts.say("The long-term warming of the environment and its resulting
change in weather patterns is called climate change.")

time.sleep(3)

tts.say("The main gases forming the greenhouse gases are carbon
dioxide, methane, nitrous oxide, and fluoride gases.")

time.sleep(3)

tts.say("Some effects of greenhouse gases are flooding, drought, increase
in sea levels, heat waves, hurricanes, and severe storms.")

time.sleep(3)

tts.say("You can reduce greenhouse emissions by reducing activities that
produce carbon dioxide gas because it is the main greenhouse gas.")

time.sleep(3)

tts.say("To reduce carbon dioxide gas, you must use renewable energy
sources such as solar energy to generate power.")
```

```
time.sleep(3)
tts.say("We should also reduce or stop using fossil fuels for power
generation and power vehicles.")
time.sleep(3)
tts.say("In addition, people should reduce indiscriminate cutting of trees.")
time.sleep(3)
tts.say("This is because trees absorb carbon dioxide from the
atmosphere.")
time.sleep(3)
tts.say("More electric cars must be used compared to fossil fuel-based
cars.")
time.sleep(3)
tts.say("Industries must use renewable energy sources to reduce carbon
dioxide emissions.")
time.sleep(3)
tts.say("We should plant more trees in our environment to absorb carbon
dioxide.")
time.sleep(3)
tts.say("In conclusion, the emission of greenhouse gases causes global
warming.")
time.sleep(3)
tts.say("Global warming causes flooding, drought, and a rise in sea level
which destroy our environment.")
time.sleep(3)
```

```
        tts.say("You shold use renewable energy to reduce greenhouse emissions.")
        self.onStopped()
        pass

    def onInput_onStop(self):
        self.onUnload() #it is recommended to reuse the clean-up as the box is stopped
        self.onStopped() #activate the output of the box
```

Testing: In this phase, the study presented Nao's presentation to a selected audience. The audience was asked for their opinion of Nao's presentation. The feedback was used to refine the code and achieve the final version. This phase of the robot storytelling also served as the pilot study of the robot presentation.

Delivery: The participants were seated at the DUT MICT Seta 4IR Centre of Excellence Computer laboratory on the day of the lesson delivery. Before that day, the participants had been given letters of information containing the lesson's purpose, procedure outline, benefits, and the process that would be used to store and disseminate the study results. They were reminded about the study's objective before being given the consent forms. The participants were asked to complete and sign the consent forms. The participants completed a pre-test, which allowed the instructor to evaluate their understanding of carbon literacy. After the test, the instructor activated the Nao robot. The robot welcomed the attendees and presented itself along with the objective of the training. The robot then began lecturing the participants on carbon literacy (see Figure 6.4). The robot storytelling presentation was repeated following the participants' request. The robot storytelling presentation lasted for about twenty minutes.

Assessment: After the robot presentation, the participants were given a five-minute break to prepare for the post-test. At the end of the short break, the students were given multiple-choice questions to answer. These multiple-choice questions aimed to assess the students' carbon literacy knowledge obtained from the robot presentation. The participants were also given questionnaires to complete, which allowed them to determine their satisfaction with the robot presentation.

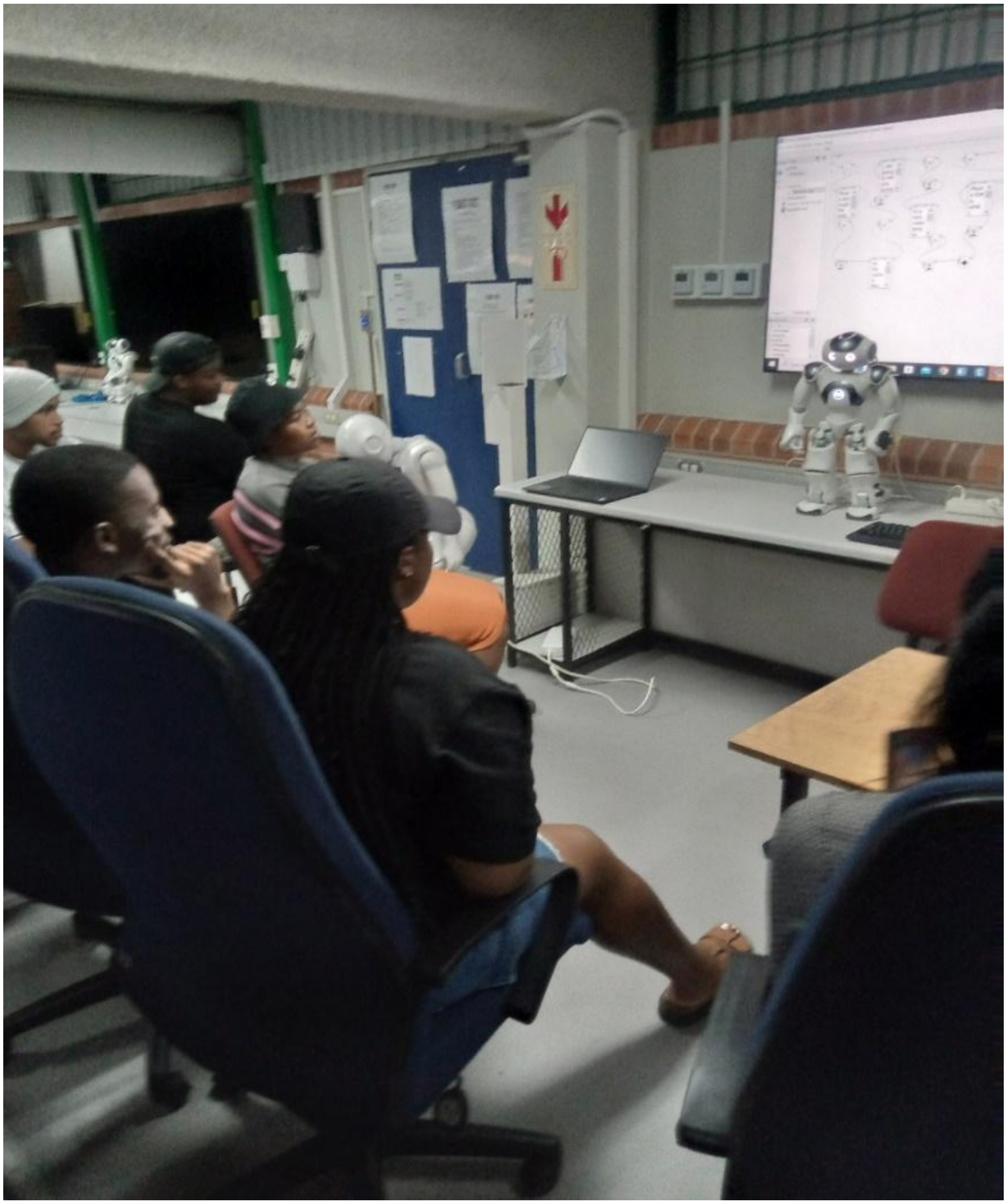

Figure 6.4: The Experimental group listening to the Nao robot presentation

6.4. Narrated PowerPoint presentation

A narrated PowerPoint presentation is a PowerPoint slide that includes narration explaining its contents. It is a way of providing commentary on the slides instead of the presenter giving oral information. This study prepared the narrated PowerPoint slides on the same topic of carbon literacy. However, the procedure for preparing this narrated PowerPoint did not follow the model used for robot storytelling. The oral commentary was recorded separately and embedded into the slides to create the narrated PowerPoint.

On the day of the lesson delivery, the participants were seated at the DUT MICT Seta 4IR Centre of Excellence Computer laboratory (see Figure 6.5). Before that day, the participants had received informational letters detailing the training's purpose, procedural framework, benefits, and methodology for storing and disseminating the study results. The teacher elucidated the study's goal to the participants and provided them with consent forms to complete and sign. They were administered a pre-test consisting of multiple-choice questions. The pre-test enabled the study to assess participants' understanding of carbon literacy before the lesson presentation. After the pre-test, the instructor began the narrated PowerPoint presentation while the participants were seated and listened. The narrated PowerPoint presentation, like the robot storytelling presentation, was repeated after the first presentation. The narrated PowerPoint presentation lasted approximately twenty minutes. After the presentation, the participants were given a five-minute break to prepare for the post-test. After the break, the participants wrote multiple-choice questions on carbon literacy. This test assesses the participants' knowledge of carbon literacy acquired from the presentation. The participants were also given questionnaires to complete, enabling the instructor to evaluate their satisfaction with the narrated PowerPoint presentation.

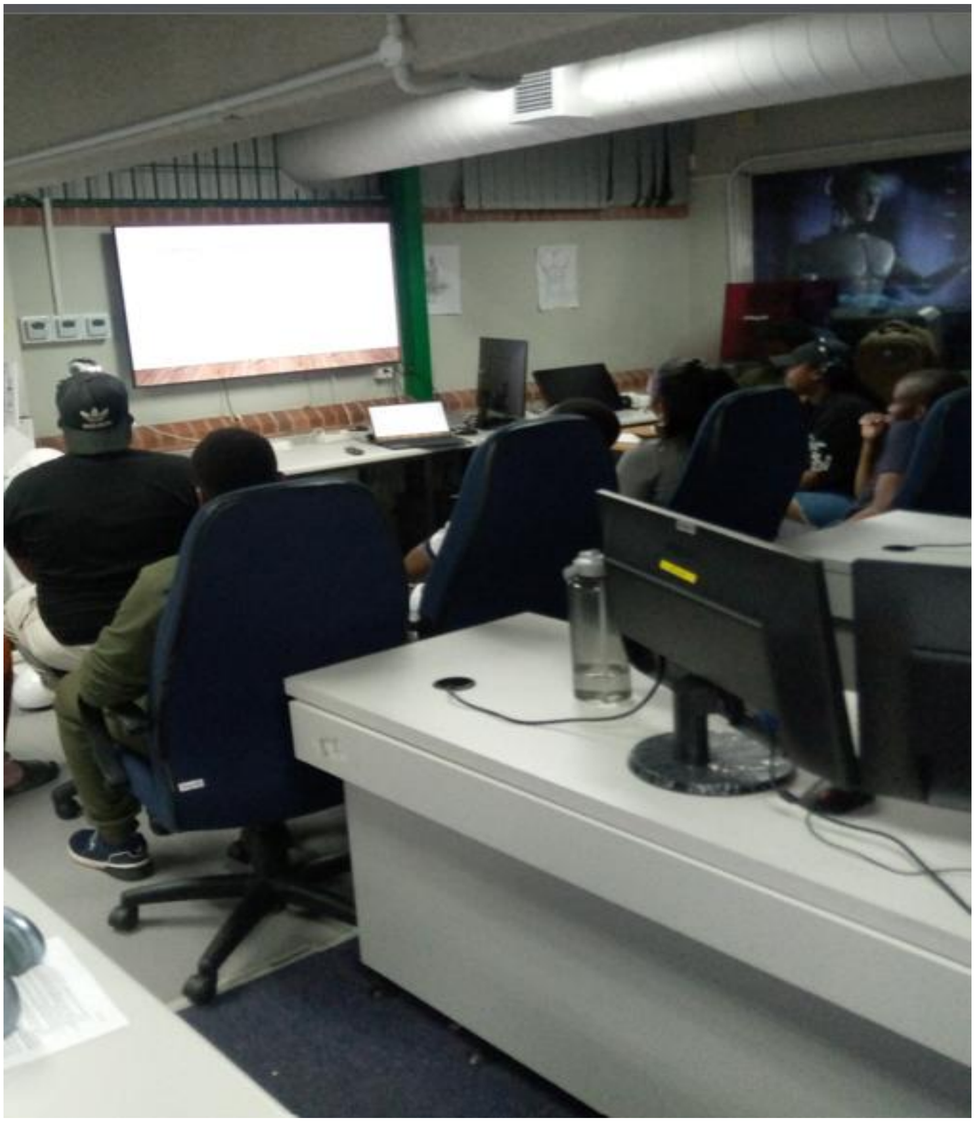

Figure 6.5: The control group listening to the narrated PowerPoint presentation.

6.5. RESULTS AND DISCUSSION

Table 6.1 presents the results of the pre-test and post-test evaluations of the experimental and control groups. Before the course began, a pre-test was administered to assess participants' proficiency in carbon literacy knowledge. The study administered post-tests after the presentations to evaluate the impact of the narrated PowerPoint and robot storytelling pieces of training on participants' carbon literacy knowledge. There were eight participants in each group.

Table 6.1: Performance of experimental and control groups

Student number	Results of the Experimental group (Robot Storytelling)		Results of the control group (Narrated PowerPoint)	
	Pre-test marks	Post-test marks	Pre-test marks	Post-test marks
01	3	5	3	4
02	3	4	4	4
03	4	5	3	3
04	3	4	3	5
05	3	5	4	4
06	3	5	2	4
07	2	5	4	4
08	2	5	3	4

6.5.1. Paired sample t-test of experimental and control group scores

A paired t-test was employed to compare the means of the pre-test and post-test for both training modalities, thereby substantiating their impact. The paired t-test is a hypothesis-testing method for analysing two data sets (Wilkerson, 2008). The data in a paired t-test are interdependent, as each value in the first sample corresponds to a value in the second sample. The parameter used for inference is the disparity between the means of the two datasets (Wilkerson, 2008). The population mean is believed to be zero (Wilkerson, 2008). The initial phase of hypothesis testing involves articulating the null hypothesis (H_0) and the alternative hypothesis (H_1) (Wilkerson, 2008). The H_0 states that the mean equals zero (Wilkerson, 2008). The H_1 states that the mean may be greater than, less than, or not equal to zero (Wilkerson, 2008). When H_1 states that the mean is smaller than zero, the test is referred to as a left-tailed test (Wilkerson, 2008). It is right-tailed when H_1 states that the mean exceeds zero (Wilkerson, 2008). A test is termed two-tailed when H_1 states that the mean is not equal to zero (Wilkerson, 2008).

The following steps were used to calculate the paired sample t-test, which compares the means of the pre-test and post-test.

Let x = pre-test score, y = post-test score, and d = difference between the pre-test and post-test scores.

1. Compute the difference between the post-test score and the pre-test score (d = y-x)
2. Determine the mean of the difference values. $\bar{d}$
3. Compute the standard deviation (SD_d) of the difference values and use the SD_d to compute the standard error of the mean difference, SE($\bar{d}$) = $\frac{Sd}{\sqrt{n}}$, where n is the number of scores or differences between the scores (Wilkerson, 2008).
4. Compute the t-value using the formula $t = \frac{\bar{d}}{SE(\bar{d})}$ This formula follows a t-distribution with n-1 degrees of freedom (Wilkerson, 2008).
5. Compare the calculated t-value in step 4 to the critical t-value from the t-distribution table at n-1 degrees of freedom (DoF) and 95% confidence level, where n is the sample size (Wilkerson, 2008).
6. Interpret the t-test based on the following: when the calculated t-value is greater than the critical t-value from the t-distribution table, the null hypothesis (H_0) is rejected; otherwise, H_0 is accepted (Wilkerson, 2008).

6.5.1.1. Paired sample t-test of the Experimental group scores

Table 6.2 shows the pre-test scores (x), post-test scores (y), and the differences between the corresponding scores (d). Table 6.2 also displays the difference values less the mean of the difference values (d - $\bar{d}$). The last column in Table 6.2 is the square of the difference values minus the mean of the difference values. The computations that follow Table 6.2 show the mean values of the pre-test scores, post-test results, and the difference values of the scores. These computations are followed by the standard deviation (SD_d) of the difference values, the standard error of the mean of difference values, and the t-value needed to test the hypotheses under this section.

Table 6.2: The difference between the pre-test and post-test scores of the Experimental group

Student Number	pre-test (x)	post-test (y)	Difference d = y-x	$d - \bar{d}$	$(d - \bar{d})^2$
01	3	5	2	0.125	0.015625
02	3	4	1	-0.875	0.765625
03	4	5	1	-0.875	0.765625
04	3	4	1	-0.875	0.765625
05	3	5	2	0.125	0.015625
06	3	5	2	0.125	0.015625
07	2	5	3	1.125	1.265625
08	2	5	3	1.125	1.265625

Mean of the pre-test scores, $\bar{x} = \frac{\sum x}{n}$

$\bar{x} = \frac{3+3+4+3+3+3+2+2}{8} = \frac{23}{8} = 2.875$

Mean of the post-test scores, $\bar{y} = \frac{\sum y}{n}$

$\bar{y} = \frac{5+4+5+4+5+5+5+5}{8} = \frac{38}{8} = 4.75$

Mean of the differences, $\bar{d} = \frac{\sum d}{n}$

$$\bar{d} = \frac{2+1+1+1+2+2+3+3}{8}$$

$$\bar{d} = \frac{15}{8}$$

$$\bar{d} = 1.875$$

The standard deviation of the differences, $SD_d = \sqrt{\frac{\sum(d-\bar{d})^2}{n-1}}$

$$SD_d = \sqrt{\frac{0.015625+0.765625+0.765625+0.765625+0.015625+0.015625+1.265625+1.265625}{8-1}}$$

$SD_d = \sqrt{\frac{4.875}{7}}$

$SD_d = \sqrt{0.6964285714}$

$SD_d = 0.835$

standard error of the mean, $SE(\bar{d}) = \frac{S_d}{\sqrt{n}}$

$SE(\bar{d}) = \frac{0.835}{\sqrt{8}} = \frac{0.835}{2.828}$

$SE(\bar{d}) = 0.295$

t-test value, $t = \frac{\bar{d}}{SE(\bar{d})}$

t-test value, $t = \frac{1.875}{0.295}$

t-test value, t = 6.356

Discussion: The mean values of the pre-test and post-test indicate that the post-test results improved over those of the pre-test. However, the t-test will verify this assertion to show whether the two means are identical. The following hypothesis was used for the t-test of the experimental group scores at a 95% confidence level and 7 (n-1) degrees of freedom (DoF).

Null hypothesis (H_0): The statistical mean values of the pre-test and post-test data are identical.

Alternative hypothesis (H_1): The statistical mean values of the pre-test and post-test data differ.

According to the computations above, the average post-test score for the robot storytelling presentation is 4.75, while the average pre-test score is 2.875. The computed t-test value is 6.356. A critical t-value from a t-distribution table in Appendix H shows the critical t-value is 2.365 at a 95% confidence level and 7 DoF. The study, therefore, rejects the null hypothesis (H0) and accepts the alternative hypothesis (H1) because the computed t-value is greater than the critical t-value from the t-distribution table. Hence, the two means differ, and therefore, the robot storytelling presentation had a positive impact on the participants' learning outcomes, as evidenced by the post-test mean being higher than the pre-test mean.

The improved performances of the students, as indicated by their post-test results compared to the pre-test, are a result of the students' enjoyment of the robot's presentation due to its gestures. This assertion is confirmed by a similar study conducted by Velentza *et al*. (2021), which used the Nao robot to teach students about the history of robots. According to Velentza *et al.* (2021), the study found that the Nao robot's cheerful personality and expressive body movement improved students' knowledge acquisition and enjoyment. In another study conducted by Vitale and Iacono (2024), the Pepper robot was used to deliver a mathematics lesson to high school students. The results showed that the Pepper robot improved listeners' engagement and enjoyment by providing immediate, personalized feedback, which significantly contributed to improving students' performance.

6.5.1.2. Paired sample t-test of the control group scores

Table 6.3 displays the scores obtained by the control group participants from the pre-test (x) and post-test (y). The Table also shows the difference in values (d) between the post-test scores (y) and their corresponding pre-test scores (x). The mean value ($\bar{d}$) of these difference values is subtracted from each difference value (d), and the result is displayed in the 5th column of Table 6.3. The 6th column in Table 6.3 shows the squares of the values computed in the 5th column. Following Table 6.3 are computations of the mean of the pre-test scores, the mean of post-test scores, the mean of the differences, the standard deviation of the differences (SD_d), the standard error of the differences, and the t-test value.

Table 6.3: The difference between the pre-test and post-test scores of the control group

Student number	pre-test score (x)	post-test score (y)	Difference (d) = (y-x)	d - $\bar{d}$	$(d - \bar{d})^2$
01	3	4	1	0.25	0.0625

02	4	4	0	-0.75	0.5625
03	3	3	0	-0.75	0.5625
04	3	5	2	1.25	1.5625
05	4	4	0	-0.75	0.5625
06	2	4	2	1.25	1.5625
07	4	4	0	-0.75	0.5625
08	3	4	1	0.25	0.0625

Mean of the pre-test scores, $\bar{x} = \frac{\sum x}{n}$

$\bar{x} = \frac{3+4+3+3+4+2+4+3}{n} = \frac{27}{8} = 3.375$

Mean of the post-test scores, $\bar{y} = \frac{\sum y}{n}$

$\bar{y} = \frac{4+4+3+5+4+4+4+4}{8} = \frac{32}{8} = 4.00$

Mean of the difference, $\bar{d} = \frac{\sum d}{n}$

$\bar{d} = \frac{1+0+0+2+0+2+0+1}{8}$

$\bar{d} = \frac{6}{8} = 0.75$

The standard deviation of the differences, $SD_d = \sqrt{\frac{\sum(d-\bar{d})^2}{n-1}}$

$SD_d = \sqrt{\frac{0.0625+0.5625+0.5625+1.5625+0.5625+1.5625+0.5625+0.0625}{8-1}}$

$SD_d = \sqrt{\frac{5.5}{7}} = \sqrt{0.7857142857} = 0.886$

standard error of the mean, $SE(\bar{d}) = \frac{S_d}{\sqrt{n}}$

$SE(\bar{d}) = \frac{0.886}{\sqrt{8}} = \frac{0.886}{2.828} = 0.313$

t-test, t = $\frac{\bar{d}}{SE(\bar{d})}$

t-test, t = $\frac{0.75}{0.313}$ = 2.396

Discussion: A comparison of the pre-test and post-test scores reveals that the narrated PowerPoint presentation had a positive impact on learning outcomes. However, this assumption can only be confirmed using a t-test to compare the pre-test and post-test means. The following hypothesis was used to compare the means using a t-test at a 95% confidence level and 7 (n-1) degrees of freedom (DoF).

Null hypothesis (H_0): The statistical mean values of the pre-test and post-test data are identical.

Alternative hypothesis (H_1): The statistical mean values of the pre-test and post-test data differ.

As shown in the computation in this section, the mean score for the narrated PowerPoint presentation post-test is 4.00, while the mean score for the pre-test is 3.25. Additionally, the computation in this section shows that the computed t-value is 2.396. The t-distribution table in Appendix H, when used to determine the critical t-value, gives a value of 2.365 at a 95% confidence level and 7 DoF. Therefore, H_1 is accepted, and H_0 is rejected since the computed t-value is higher than the corresponding t-value from the t-distribution table in the appendix. Rejecting H_0 indicates that the two means differ. Therefore, the narrated PowerPoint presentation enhanced participants' learning outcomes, as evidenced by the higher mean score on the post-test compared to the pre-test.

Like the robot storytelling, the PowerPoint presentation also improved students' performance. This improvement in students' performance implies that the control group also liked the PowerPoint presentation. The improved outcome of the control group is similar to that of a study conducted by Zerei *et al.* (2021), which used digital storytelling with PowerPoint to deliver instruction on oncology and hematology to medical students. According to the study, the use of digital storytelling in PowerPoint enhanced students' critical thinking and improved their communication skills, ultimately leading to better learning outcomes.

6.5.2. Independent Samples t-test of experimental and control group post-test Scores

Unlike the previous sections, which used paired t-tests, also known as dependent t-tests, this section employs an independent t-test to compare the post-test results of the experimental and control groups. The following steps were used to calculate the independent sample t-test, comparing the post-test results of the control and experimental groups.

1. Compute the means of the control group ($\bar{Y}$) and experimental group ($\bar{X}$) post-test scores. $\bar{Y} = \frac{\sum Y}{n}$ and $\bar{X} = \frac{\sum \bar{X}}{n}$
2. Compute the standard deviation of the two samples. $SD_X = \sqrt{\frac{\sum(X-\bar{X})^2}{n-1}}$ and $SD_y = \sqrt{\frac{\sum(Y-\bar{Y})^2}{n-1}}$
3. Calculate the independent t-test value. $T = \frac{\bar{X}-\bar{Y}}{\sqrt{\left(\frac{s_X{}^2}{n1}\right)+\left(\frac{s_y{}^2}{n2}\right)}}$
4. Compare the calculated t-value in step 3 to the critical t-value from the t-distribution table at $n_1 + n_2 - 2$ degrees of freedom (DoF) and 95% confidence interval, where n_1 and n_2 are the sample sizes of the experimental and control groups.
5. Interpret the t-test based on the following: when the calculated t-test value is greater than the critical t-value from the t-distribution table, the Null hypothesis (H_0) is rejected; otherwise, the H_0 is accepted.

Table 6.4 presents the post-test scores of the experimental and control groups, including the differences between the scores and their respective means. The table also shows the squares of the differences between the scores and the means used to calculate the standard deviation of the two groups' scores. There are eight scores in each group. The computation that follows Table 6.4 shows the mean values of both groups' scores. Additionally, the calculation reveals the standard deviation of the two groups and, consequently, the independent t-test values.

Table 6.4: Post-test scores of the experimental and control groups

Student number	Experimental group scores (x)	control group scores (y)	$X - \bar{X}$	$(X - \bar{X})^2$	$Y - \bar{Y}$	$(Y - \bar{Y})^2$
	5	4	0.25	0.0625	0	0
	4	4	-0.75	0.5625	0	0
	5	3	0.25	0.0625	-1.00	1.00
	4	5	-0.75	0.5625	1.00	1.00
	5	4	0.25	0.0625	0	0
	5	4	0.25	2.0625	0	0
	5	4	0.25	0.0625	0	0
	5	4	0.25	0.0625	0	0

The mean score of the experimental group, $\bar{X} = \frac{\sum X}{n}$

$$\bar{X} = \frac{5+4+5+4+5+5+5+5}{8}$$

$$\bar{X} = 4.75$$

The mean score of the control group, $\bar{Y} = \frac{\sum y}{n}$

$$\bar{Y} = \frac{4+4+3+5+4+4+4+4}{8}$$

$$\bar{Y} = 4.00$$

The standard deviation of the experimental group, $SD_x = \sqrt{\frac{\sum(X-\bar{X})^2}{n-1}}$

$SD_x = \sqrt{\frac{0.0625+0.5625+0.0625+0.5625+0.0625+0.0625+0.0625+0.0625}{8-1}}$

$SD_x = 0.463$

The standard deviation of the control group, $SD_y = \sqrt{\frac{\sum(Y-\bar{Y})^2}{n-1}}$

$SD_y = \sqrt{\frac{0+0+1+1+0+0+0+0}{8-1}}$

$SD_y = 0.535$

Independent t-test, $t = \frac{\bar{X}-\bar{Y}}{\sqrt{\left(\frac{s_X{}^2}{n1}\right)+\left(\frac{s_y{}^2}{n2}\right)}}$

Independent t-test, $t = \frac{4.75-4.00}{\sqrt{\frac{0.463^2}{8}+\frac{0.535^2}{8}}}$

Independent t-test t = 2.998

Degrees of freedom, DoF= n1 + n2 – 2 = 8+8-1 = 14

Confidence level = 95%

Discussion: The post-test scores revealed that the experimental and control groups performed better than expected. However, an independent t-test was used to compare the means of the two groups to determine if they performed equally. The following hypothesis was set to assess the equality of the means of the two groups.

Null hypothesis (H_0): The statistical mean values of the narrated PowerPoint post-test scores and those of robot storytelling are identical.

Alternative hypothesis (H_1): The statistical mean values of the post-test outcome for narrated PowerPoint training and robot storytelling differ.

According to the computation under this section, the mean value of the robot storytelling outcomes is 4.75, which is more significant than the mean value of 4.00 from the narrated PowerPoint presentation results. The calculation produced a t-test value of 2.998. From the t-distribution table in Appendix H, the critical t-value is 2.145 at a 95% confidence level and 14 DoF. The calculated value exceeds the critical t-value obtained from the t-distribution. The comparison of these two t-values implied that the study rejects H_0. This hypothesis testing accepts H_1, which means the two mean scores are not identical. Therefore, the robot storytelling presentation produced a better learning experience than the narrated PowerPoint presentation, as evidenced by the experimental group's mean being higher than that of the control group.

Although both robot storytelling and PowerPoint presentations improved their respective groups' performance in the above discussions, as indicated by the post-tests compared with the pre-tests. Here, comparing the two post-tests enables the study to determine which digital storytelling method is more effective in improving learning outcomes. As mentioned above, the robot storytelling method outperformed the PowerPoint presentation. The study outcomes confirm a study conducted by Chen Hsieh and Lee (2023). The study by Chen Hsieh and Lee (2023) was used to examine the relationship between digital storytelling outcomes, emotions, and grit in robot and PowerPoint presentations. The result was that the robot enhanced students' levels of grit, positive emotions, and self-perceptions more effectively than the PowerPoint presentation. The robot presentation also fostered greater interaction with the students, making learning an engaging and enjoyable experience and thereby improving learning outcomes compared to the PowerPoint presentation.

6.5.3. Independent sample t-test of means of questionnaire responses using SPSS

Table 6.5 was used to assign values to the corresponding answers in the questionnaire, allowing for the analysis of responses using an independent t-test. For instance, the study assigns five points to the answers: Very clear, Extremely satisfied, Highly motivated, Highly enjoyed, and Very interesting.

Table 6.5: Values allocated to questionnaire responses.

The value allocated to responses.	Responses for dimensions				
	Clarity	Interest	Motivation	Enjoyment	Satisfaction
5	Very clear	Very interesting	Highly motivated	Highly enjoyed	Extremely satisfied
4	Clear	Interesting	Motivated	Enjoyed	Satisfied
3	Moderately clear	Moderately interesting	Moderately motivated	Moderately enjoyed	Moderately satisfied
2	Slightly clear	Slightly interesting	Slightly motivated	Slightly enjoyed	Slightly satisfied
1	Not clear	Not interesting	Not Motivated	Not enjoyed	Not satisfied

Table 6.6 presents each dimension and the scores for each question based on the responses from the experimental and control groups. These scores were used to calculate the mean score for each question for comparison.

Table 6.6: Tally of responses

Dimension	Experimental group	control group
Clarity	5, 5, 4, 5, 5, 5, 5, 4,	5, 4, 4, 4, 5, 4, 5, 4,
Interest	4, 4, 4, 5, 4, 5, 5, 5,	4, 4, 4, 4, 5, 4, 4, 3,
Motivation	3, 4, 4, 4, 4, 4, 5, 4,	4, 3, 5, 5, 5, 4, 4, 3,
Enjoyment	5, 4, 4, 4, 4, 5, 5, 5,	4, 4, 4, 4, 5, 4, 3, 3,
Satisfaction	5, 5, 5, 4, 4, 5, 5, 5,	5, 4, 5, 4, 5, 4, 4, 4,

The t-test computation of the questionnaire responses was processed using SPSS software (IBM Corp., 2017). An independent sample t-test, as performed with SPSS (IBM Corp., 2017), requires testing and grouping variables. The testing variables (dimensions) are clarity, interest, motivation, enjoyment, and satisfaction, and the grouping variables are experimental and control groups, as shown in Table 6.7.

Table 6.7: Dimensions and their values

Group id	Clarity	Interest	Motivation	Enjoyment	Satisfaction
Experimental group					
01	5	4	3	5	5
01	5	4	4	4	5
01	4	4	4	4	5
01	5	5	4	4	4
01	5	4	4	4	4
01	5	5	4	5	5
01	5	5	5	5	5
01	4	5	4	5	5
Control group					
02	5	4	4	4	5
02	4	4	3	4	4
02	4	4	5	4	5
02	4	4	5	4	4
02	5	5	5	5	5
02	4	4	4	4	4
02	5	4	4	3	4
02	4	3	3	3	4

The group statistics for the five aspects (test variables) of the questionnaire—clarity, interest, motivation, enjoyment, and satisfaction—are displayed in Table 6.8. The experimental and control groups provided eight responses (N) to each dimension. The mean, standard deviation, and standard error of the mean for each group response are also shown in Table 6.8. The standard error of the mean calculates the likelihood that the sample mean will deviate from the actual population mean (Wilkerson, 2008). In contrast, the standard deviation illustrates how the scores allocated to the replies vary around the mean (Wilkerson, 2008).

Table 6.8: Group Statistics of clarity, interest, motivation, enjoyment, and satisfaction of robot storytelling and narrated PowerPoint training (IBM Corp., 2017)

	Group	N	Mean	Std. Deviation	Std Error Mean
Clarity	Robot storytelling	8	4.75	0.463	0.164
	Narrated PowerPoint	8	4.38	0.518	0.183
Interest	Robot storytelling	8	4.5	0.535	0.189
	Narrated PowerPoint	8	4.00	0.535	0.189
Motivation	Robot storytelling	8	4.00	0.535	0.189
	Narrated PowerPoint	8	4.12	0.835	0.295
Enjoyment	Robot storytelling	8	4.50	0.535	0.189
	Narrated PowerPoint	8	3.88	0.641	0.227
Satisfaction	Robot storytelling	8	4.75	0.463	0.164
	Narrated PowerPoint	8	4.38	0.518	0.183

The data for the independent sample t-test of the dimensions questioned in the questionnaires are presented in Table 6.9. "Variances assumed equal" and "Variances assumed not equal" are two phrases that appear in the first column, along with the names of the dimensions. The groups are compared using the matching values in the "variance assumed equal" row if the sig value is more significant than 0.05. The values in the other row, where identical variances are not expected, are utilized in the comparison if the sig value is less than 0.05. The degrees of freedom (DoF) and computed t-value are also included in Table 6.9. An independent t-test obtains its DoF from the formula $(n_1+n_2) - 2$ (Ken State University, 2024) when variances are assumed equal. However, a different formula is used to calculate DoF if variances are assumed not to be equal, which was not applied in this study. In Table 6.9, DoF is (8+8) – 2 = 14. Table 6.9 also contains the Sig (2-tailed) values, the mean difference, and the standard error of the difference, along with the 95% confidence interval.

Table 6.9: Independent Samples t-test of clarity, interest, motivation, enjoyment, and satisfaction of robot storytelling and narrated PowerPoint training (IBM Corp., 2017)

		Levene's Test for Equality of Variances		T-test for Equality of Means						
									95% confidence interval of the Difference	
		F	Sig.	t	DoF	Sig. (2-tailed)	Mean difference	Std. Error Difference	Lower	Upper
Clarity	Variances assumed equal	1.000	0.334	1.528	14	0.149	0.375	0.245	-0.152	0.902
	Variances assumed not equal.			1.528	13.829	0.149	0.375	0.245	-0.152	0.902
Interest	Variances assumed equal	2.333	0.149	1.871	14	0.082	0.500	0.267	-0.073	1.073
	Variances assumed not equal.			1.871	14	0.082	0.500	0.267	-0.073	1.073
Motivation	Variances assumed equal	3.155	0.097	-0.357	14	0.727	-0.125	0.350	-0.876	0.626
	Variances assumed not equal.			-0.357	11.916	0.728	-0.125	0.350	-0.889	0.639
Enjoyment	Variances assumed equal	0.163	0.693	2.118	14	0.053	0.625	0.295	-0.008	1.258
	Variances assumed not equal.			2.118	13.563	0.053	0.625	0.295	-0.010	1.260
Satisfaction	Variances assumed equal	1.000	0.334	1.528	14	0.149	0.375	0.245	-0.152	0.902
	Variances assumed not equal.			1.528	13.829	0.149	0.375	0.245	-0.152	0.902

DISCUSSION: The study analyzed the participants' responses to the questionnaires and their satisfaction with the delivered lesson. The analysis employed an independent t-test to compare the average values of the responses between the experimental and control groups. The following hypotheses were used to compare the average scores of each dimension or testing variable.

Null hypothesis (H_0): The mean values of the scores obtained from the experimental and control groups' responses are identical.

Alternative hypothesis (H_1): The mean values of the scores obtained from the experimental and control groups' responses differ.

The robot storytelling group responses had a mean clarity dimension score of 4.75, which is closer to the mean value of 4.38 for the narrated PowerPoint group responses (Table 6.8). These two mean values suggest that the experimental and control groups' presentation approach was understood, as shown in Table 6.6.

Table 6.9 shows that Levene's Test for Equality of variances has a p-value of 0.334, more significant than 0.05 ($p>\alpha$) (IBM Corp., 2017). According to this p-value, the means of the responses from the two groups will be compared in Table 6.9, assuming equal variances (as shown in the 'variances assumed equal' row). At a 95% confidence interval and 14 DoF, the critical t-value from the t-distribution table in Appendix H is 2.145, but the computed t-value from Table 6.9 is 1.528. The calculated t-value is less than the critical t-value. Therefore, H_0 is accepted, and H_1 is rejected. The rejection of H_1 indicates no significant difference exists in the mean values of the replies from the experimental and control groups.

Table 6.8 shows that the respective mean values for the interest dimension in the experimental and control groups are 4.50 and 4.00. The two groups indicated that their respective methodologies are fascinating, as indicated by the values in Table 6.6. The critical t-value from the t-distribution table in Appendix H is 2.145. However, the computed t-value from Table 6.9 is 1.871. The critical t-value exceeds the computed t-value. Therefore, H_0 is accepted, and H_1 is rejected. It is implied that there is no significant difference between the mean values of the replies from the two groups if the null hypothesis (H_0) is accepted. Therefore, the two groups showed equal interest in their presentations.

Table 6.8 shows that the experimental group’s motivation response mean is 4.00, while the control PowerPoint group's is 4.12. These two mean values suggest that the experimental and control group participants were motivated by their different presentation approaches. Variances are assumed equal since, similar to other dimensions covered previously, the p-value from Levene’s Test is more significant than 0.05 (see Table 6.9). The t-distribution table (see Appendix H) shows that the critical t-value is 2.145, while Table 6.9 shows that the computed t-value is -0.357. A comparison between the computed and critical t-values reveals that the former is smaller. As a result, H_1 is rejected, and H_0 is accepted. Accepting H_0 means the two mean values are identical, so the respective presentation motivated the groups.

The robot storytelling group's mean value is 4.50, whereas the narrated PowerPoint group's is 3.88, according to the group data of the enjoyment dimension in Table 6.8. The experimental group appears to have liked their instruction, as indicated by a mean value of 4.50, whereas the control group's mean value of 3.88 suggests a moderate degree of liking. The critical t-value from the t-distribution table (see Appendix H) is 2.145. However, the computed t-value from Table 6.9 is 2.118. The critical t-value exceeds the computed t-value. As a result, H_1 is rejected, and H_0 is accepted. Accepting H_0 implies that the means of the two groups' responses are not significantly different; therefore, they enjoyed their respective presentation with no significant difference.

According to the group statistics, the mean scores for narrated PowerPoint and robot storytelling satisfaction are 4.75 and 4.38, respectively (see Table 6.8). These two mean values indicate that both groups expressed high satisfaction with their instruction. Additionally, the p-value of 0.334 from Table 6.9's Levene’s Test for Equality of variances is more significant than 0.05, indicating that the variances are assumed equal. From Table 6.9, the calculated t-value is 1.528, and the critical t-value from the t-distribution table in Appendix H is 2.145. When the two t-values are compared, the computed t-value is less than the critical t-value, implying that H_0 is accepted. The H_1's rejection suggests that the two means are identical and that the two groups were equally satisfied with their respective methods of presentation.

The questionnaire responses from both the experimental and control groups have shown that both groups were satisfied with their respective presentations. However, the differences in learning outcomes may be due to the robot's attractive gestures in its presentation, as this made the students pay more attention to the robot's presentation. A study conducted by Bono *et al.* (2020) used the ACT-R (Adaptive Control of Thought – Rational) model to create story characters, Nao and Pepper robots, to tell stories to selected children. The study's results show that the robot characters captured the audience's attention and curiosity regarding both the plot and the characters' fate. The study by Bono *et al*. (2020) supports the reason why the experimental group performed better than the control group, as discussed above. However, both groups were satisfied with their respective presentations.

6.5.4. Summary of the discussion

- Robot-assisted digital storytelling improved students' learning outcomes on carbon literacy.
- The narrated PowerPoint presentation also improved students' learning outcomes in terms of carbon literacy.
- A robot-assisted digital storytelling presentation yielded a better learning outcome than the narrated PowerPoint training.
- The robot storytelling and narrated PowerPoint presentations were clear and engaging. The members of both the experimental and control groups felt motivated and satisfied. Ultimately, both groups enjoyed their respective presentations.

6.6. Summary

This chapter employed robot-assisted digital storytelling and a narrated PowerPoint presentation to deliver a lesson on carbon literacy to a select group of students, aiming to enhance their understanding of the topic. The selected students were divided into two groups: an experimental group and a control group. The experimental group was trained using robot-assisted digital storytelling, while the control group was trained using a narrated PowerPoint presentation. Before the lessons, the students wrote a pre-test to assess their knowledge of carbon literacy. A post-test was also conducted at the end of the lesson delivery to find out the carbon literacy knowledge acquired through the training. The study found that both robot-assisted digital storytelling and the narrated PowerPoint presentation improved students' understanding of carbon literacy. However, robot-assisted digital storytelling enhanced students' knowledge better than the narrated PowerPoint presentation. The study also found that both the experimental and control groups were satisfied with their respective method of presentation. The results of this experiment suggest that robot-assisted digital storytelling enhances learners' engagement, motivation, and learning outcomes in carbon literacy training.

CHAPTER SEVEN

Research Conclusion, Limitations, and Recommendations

This chapter concludes the study by summarizing the preceding chapters and describing how the study objectives were achieved to address the research questions. It also discusses the study's findings, concludes the entire research, highlights the study's limitations, and provides recommendations for practitioners and future research.

7.1. Summary of the study report

The research purpose was to propose a robot-assisted digital storytelling model that improves learner motivation, engagement, and learning objectives in carbon literacy for green innovation and entrepreneurship training. The study employed the design science research paradigm, following the steps outlined in the design science process model for its activities. As a result, the study developed a six-element robot-assisted digital storytelling model, which was validated through expert review and user-based evaluation. The following are the summaries of the chapters.

The first chapter explained climate change and carbon literacy, highlighting the need to educate the masses on carbon literacy to reduce individual and organizational carbon footprints. The chapter also introduced humanoid and social robots, digital storytelling (DST), and various digital storytelling platforms. The chapter provided the problem statement, research questions, aim, and thesis objectives. The chapter further explains the motivation for this PhD thesis and states the thesis's contribution. The chapter concluded with an outline of the thesis report's organization.

The second chapter lays the foundation for the thesis by providing an overview of existing research on robot-assisted digital storytelling (RA-DST) and identifying gaps in the field. A review of digital storytelling (DST) was presented at the beginning of the chapter. It also briefly discussed the history of DST, the many types of DST platforms, and the applications of DST. The review discovered four leading DST platforms: social robot platforms, social media platforms, online/web-based platforms, and computer-based/mobile device software platforms. A review of digital storytelling models followed the review of digital storytelling platforms. This model review found that most models developed by experts in digital storytelling are not suitable for creating robot storytelling. The reason is that the models did not consider the programming aspects of robot storytelling. In addition, the models developed by those experts are not favourable for instructional delivery, as they lack evaluation as part of the model elements. Aside from the model review, the study conducted a scoping review to confirm any gaps in robot storytelling. The scoping review revealed that robot storytelling is primarily used in educational institutions to convey instructions and information. However, no published model was suitable for preparing robot-assisted digital storytelling to deliver instructions to pupils and students. This revelation motivated the study to propose a robot-assisted digital storytelling model for carbon literacy training or for delivering carbon literacy instructions.

The third chapter was used to comprehensively examine humanoid robot technology, facilitating readers' understanding of the characteristics of robots employed in storytelling. The overview discussed the parts of the humanoid robot body frame, including the head, joints, manipulators, end effectors, and legs. The overview also discussed the robot's main electronic components that control its operations. The main electronic components are sensors, actuators, and microcontrollers. The microcontrollers are the programmable units that direct the actions of the robots. The microcontrollers receive sensor inputs and send instructional outputs to the actuators for action. The overview found two main methods of programming robots: lead-through programming and offline programming. The lead-through is used for industrial robots, while the offline programming is used for social robots.

The fourth chapter explained the paradigm that served as the basis for the research, the research methodologies utilized, and the ethical considerations associated with this thesis. A research paradigm and its foundations were discussed at the beginning of the chapter. These foundations included ontology, epistemology, methodology, and axiology. Additionally, the various research paradigms were presented and discussed. After that, the chapter proceeded to define the paradigms that constitute the foundation of the research, namely the pragmatic paradigm and the design science research paradigm. The study design incorporated various research approaches following the pragmatic paradigm. The actions carried out at each study stage are also discussed in this chapter. The six steps that comprise the design science process model were also described. The process model includes a problem identification and motivation stage, a solution objectives stage, a design and development stage, a demonstration stage, an assessment stage, and a communication stage. Finally, the chapter explained the ethical concerns associated with this thesis, sampling strategy, and participant recruitment.

The fifth chapter was used to design and develop a robot-assisted storytelling model suitable for carbon literacy training. The model was developed using existing procedures and activities of researchers and instructors who have created robot storytelling systems to deliver instructions. The model development followed a customized method that combined meta-synthesis and content analysis to extract and code the procedures and activities involved in creating robot storytelling. The final proposed model had six elements: storytelling requirements, preparation, programming, testing, delivery, and assessment. The developed model was submitted to two information technology lecturers for review. The reviewers initially proposed some corrections, which were implemented, and the model was finally approved in the second round.

The sixth chapter evaluated the established model based on user feedback. The proposed model was experimented with by creating robot storytelling on carbon literacy to train a select group of undergraduate students and improve their knowledge of carbon literacy. Another training session was conducted for selected undergraduate students using a narrated PowerPoint presentation for comparison. The learning outcomes of these training pieces were evaluated. According to the evaluation, robot storytelling enhanced students' knowledge of carbon literacy, and the PowerPoint presentation also improved participants' understanding of carbon literacy. However, robot storytelling training improved learning outcomes more than the narrated PowerPoint presentation.

7.2. How the study objectives were achieved to address the research questions

The following are the research questions that this study sought to answer. The questions helped to identify the research problem that this study investigates.

Research question one: How can a robot-assisted digital storytelling model be developed based on existing research in robot storytelling to enhance learner motivation, engagement, and learning outcomes in carbon literacy for Green Innovation and Entrepreneurship (CL4GIE) training?

Research question two*: How can the proposed robot-assisted digital storytelling model be validated?*

Research question three: *How can the proposed robot-assisted digital storytelling model be experimented with to train selected undergraduate students in carbon literacy?*

The following research objectives were selected to answer the research questions posed to direct the investigation. Under each stated purpose, the task associated with the objective and how it was carried out are also described.

Research objective one: *To identify digital story elements (DSEs) required for a robot-assisted digital storytelling model that enhances learner motivation, engagement, and learning outcomes in carbon literacy for green Innovation and entrepreneurship (CL4GIE) training.*

The task for the study, in relation to this objective, was to identify the digital story elements necessary to create the proposed robot-assisted digital storytelling model. The objective task was achieved by identifying research articles on robot storytelling that created robot storytelling systems to deliver instructions to audiences. Twenty articles were identified that met the selection criteria established by the study. The content analysis method was employed to determine the elements, activities, and strategies utilized by the selected articles in creating and delivering robot storytelling training to their target audiences.

Research objective two: *To develop a robot-assisted digital storytelling model incorporating the identified digital story elements.*

The task associated with this objective for the study was to identify a systematic method for creating the proposed model using the identified storytelling elements. The study employed a customized qualitative meta-synthesis to code the extracted storytelling elements and categorize the coded elements. The final model was framed from the categorized storytelling elements.

Research objective three: *To evaluate the model's performance for enhanced learner motivation, engagement, and learning outcomes in CL4GIE training.*

The study's primary objective was to subject the model to expert and user-based evaluations. After the model was framed, it was presented to two Information Technology lecturers with over ten years of teaching experience to assess the model creation process and provide recommendations for any necessary corrections. The reviewers first recommended some corrections, which were effected, and the model document was presented to them again for approval. The second evaluation applied to the model was user-based. The proposed model served as a guide to create robot storytelling that delivered carbon literacy instructions to a select group of undergraduate students. The learning outcomes of the training or instruction were assessed, and the results showed that the robot storytelling instruction improved learner motivation, engagement, and learning outcomes.

Research objective four: *To compare the implementation of robot-assisted digital storytelling for CL4GIE training to computer-based digital storytelling for CL4GIE training.*

The study's responsibility in achieving objective four was to create computer-based digital storytelling to deliver carbon literacy instructions and compare the learning outcomes of computer-based digital storytelling with those of robot storytelling. Based on this task, the study developed a narrated PowerPoint presentation on carbon literacy and delivered it to a select group of undergraduate students. The learning outcomes were assessed and compared to those of the robot storytelling. The comparison revealed that the learning outcomes of the robot storytelling training were better than those of the narrated PowerPoint training.

7.3. Summary discussion of the study findings

This study proposed a six-element robot-assisted digital storytelling model. The model's elements are storytelling requirements, preparation, programming, testing, delivery, and assessment. A scoping review conducted by this study revealed that no published robot storytelling model incorporates elements that include storytelling requirements and testing, which are essential components in any programming module, software development, and robot storytelling development. In addition, existing digital storytelling models proposed by experts in digital storytelling are not favourable for storytelling applications for training or instructional delivery. This assertion is based on the fact that existing digital storytelling models do not include evaluation as a key element. Any training activity or instructional delivery requires evaluation at the end of the delivery to assess the outcome. The proposed model from this study encompasses all the relevant elements necessary to create robot-based storytelling instruction or training. The following are brief descriptions of the model's key elements.

The storytelling requirement element phase identifies and selects hardware and software tools to create the storytelling system. This phase also determines the story topic, purpose, and objectives. The preparation phase involves creating multimedia elements, including audio, video, images, text, and animation. This phase also recommends preparing the story plot and storyboard. The creation of storytelling architecture is recommended in this phase. The third element of the proposed model is programming. After completing the storytelling requirements and preparation phases, this phase is used to program the robot. During this phase, multimedia elements are uploaded into the robot's memory in addition to the program code. This phase also configures the robot with gestures and gazing behaviour. The testing phase constitutes the fourth element of the model. This phase tests the robot storytelling system to check the speed at which the robot speaks, the clarity of the robot's presentation, and the gestures displayed by the robot. Checking all these parameters during the testing phase results in a robot storytelling system that produces a more effective presentation.

The delivery phase presents the instructions or training to the audience. This phase is the fifth element of the proposed model. Before the instructional delivery, letters of information detailing the purpose of the training are given to the audience to read. The purpose of the training or instructional delivery can also be delivered orally to the audience. Consent forms are provided to the audience or participants to fill out and sign. The last element is the assessment phase. This phase or element assesses or evaluates the training or instructional delivery outcomes. The assessment tool can take the form of written or oral tests or interviews. The assessment enables trainers or instructors to evaluate the training outcomes and determine its success.

The effectiveness of the proposed model was assessed when it was used to prepare robot storytelling for training selected undergraduate students in carbon literacy. The outcome was compared to similar training provided to undergraduate students using a narrated PowerPoint presentation. The comparison results showed that the robot storytelling presentation produced better learning outcomes than the narrated PowerPoint presentation. Hence, the robot storytelling prepared using the proposed model as a guide produced enhanced learning outcomes.

7.4. Conclusion

This study aimed to propose a robot-assisted digital storytelling model for creating robot storytelling instruction or training that enhances learner motivation, engagement, and learning outcomes in carbon literacy. The study employed the design science research paradigm, which follows the design science process model to create the proposed artifact. Following the content analysis method, the study identified robot storytelling methods and strategies employed by researchers to develop and deliver robot storytelling instructions. The identified robot storytelling methods or elements were coded using qualitative meta-synthesis to propose a six-element model for creating robot storytelling instruction or training. The model was submitted to two Information Technology lecturers for review, who recommended some corrections and approved the model. Following the expert review, the model was utilized to develop robot-assisted storytelling instruction in carbon literacy, training a select group of undergraduate students. The learning outcomes of the robot storytelling instruction were compared to the outcomes of similar training using a narrated PowerPoint presentation. The assessment of the outcomes of the two training pieces showed that both improved learning outcomes. However, the robot storytelling training enhanced learning outcomes more effectively than the narrated PowerPoint training and improved learner motivation and engagement.

7.5. Limitations of the study

The amount of research articles published on robot storytelling is not encouraging, which was one of the study's limitations. Following a search of the most prominent electronic databases, including Scopus, Web of Science, and Lens, only twenty research articles were identified as suitable for the study, which could be utilized in the model creation process. Additionally, the Nao robot used in the experiments had a limited set of capabilities, which was another limitation of this study. Because the Nao robot could not play music or video, the robot's storytelling presentation consisted solely of speaking and making gestures. Finally, the pre-test and post-test questions were not enough to cover the entire carbon literacy course. The insufficient questions mean that the evaluation conducted was not sufficient to assess the full extent of the trainees' carbon literacy knowledge.

7.6. Recommendations

The study recommends employing robot storytelling to deliver carbon literacy education and promote climate awareness in schools. In addition, manufacturers of social robots should produce more social robots that can play music and display images, as well as talk, to enable instructors to deliver engaging lessons to learners. Programmers should create more user-friendly applications for practitioners to program social robots.

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Appendix: A

INFORMATION LETTER

Title of the Study: A Carbon Literacy for Green Innovation and Entrepreneurship Humanoid Robot-Assisted Digital Storytelling Model

Principal Investigator/researcher: George Essien, PhD student, Information Technology Department, DUT

Supervisor: Dr. Steven Parbanath, Information Systems Department, DUT.

Brief Introduction and Purpose of the Study: The term digital storytelling (DST) refers to the process of conveying a narrative through the utilization of various digital technologies and media: audio, video, art, graphics, pictures, and texts. There are several platforms for creating digital storytelling. Some of these platforms include web-based and robot-assisted platforms. Robot-assisted digital storytelling allows a robot to present stories to the audience. This study will develop a robot-assisted digital storytelling model to train selected participants on Carbon Literacy for Green Innovation and Entrepreneurship (CL4GIE). The model represents a graphic representation of generating and sharing robot stories.

Present yourself to the participant: Please let me know how you are doing. I introduce myself as George Essien. The Department of Information Technology, DUT, is where I am currently doing my doctoral degree. I hold a Master of Telecommunications Management and a Bachelor of Science in Computer Engineering. I am currently undertaking a PhD research in robotics and digital storytelling. I have invited you here to take part in this research. Thank you.

Invitation to prospective participants: Dear Student of the DUT, I invite you to participate in a PhD research study I am now conducting. The study is titled "A Carbon Literacy for Green Innovation and Entrepreneurship Humanoid Robot-Assisted Digital Storytelling Model." With your participation, you will have the opportunity to receive training in Carbon Literacy for Green Innovation and Entrepreneurship. This training will be delivered through a PowerPoint presentation and robot storytelling. As part of your involvement, you must listen to short stories about robots and see a PowerPoint presentation about carbon literacy. After listening to the PowerPoint presentation and the robot story, you will be asked to respond to a few questions based on the presentation involving multiple-choice answers. Participation is voluntary, and you can withdraw from the study at any time. The research is conducted in complete secrecy. Consequently, you don't need to enter your name or any other information that could be used to identify you.

Outline of the Procedures: This work seeks to create a Humanoid Robot-assisted Digital Storytelling Model for Carbon Literacy in Green Innovation and Entrepreneurship (CL4GIE) training.

. The specific objectives are:

i. To identify Digital Story Elements (DSEs) required for a robot-assisted digital storytelling model that enhances learner motivation, engagement, and learning outcomes in carbon literacy for Green Innovation and Entrepreneurship (CL4GIE) training.
ii. To develop a robot-assisted digital storytelling model incorporating the identified digital story elements.
iii. To evaluate the model's performance for enhanced learner motivation, engagement, and learning outcomes in CL4GIE training.
iv. To compare robot-assisted digital storytelling for CL4GIE training implemented using the proposed model to computer-based digital storytelling.

Your participation will be in line with objective numbers 3 and 4 and involve the following activities:

i. The storytelling activities will occur at the DUT MICT Seta 4IR Centre of Excellence computer laboratory.
ii. You will be given seats to relax comfortably.
iii. After a few minutes, you will be given five multiple-choice questions to answer. Note: if you do not know the answer to a question, you can leave it unanswered.
iv. After responding to the questions, you will be divided into two groups using a random method, and the groups will be named experimental and control groups.
v. The control group will be asked to wait about fifteen minutes outside the laboratory while I attend the Experimental group to listen to the robot storytelling.
vi. Before the robot begins its storytelling, I will allow you (the experimental group) to ask questions about anything you do not understand or need clarification.
vii. The robot will greet you and then tell the story on carbon literacy
viii. You will listen attentively to the storytelling
ix. This presentation will last for about 10 minutes
x. After the storytelling, you will answer a few multiple-choice questions based on your understanding and satisfaction with the storytelling. Note that you are at liberty not to answer a question if you do not know the answer.
xi. After I have finished with you (the Experimental group), you will also wait outside the laboratory while the control group enters the laboratory for their training.
xii. I will present the same carbon literacy training to the control group through PowerPoint presentation, not robot storytelling.
xiii. After the PowerPoint presentation, the control group will also respond to similar multiple-choice questions to which the Experimental group responded.

Potential Risks or Discomforts to the Participant: This study presents no risks or discomforts to you.

Clarify the reasons for potential withdrawal from the study to the participant: Participants may be disqualified if they do not complete the training segment. In this circumstance, the individual will be prohibited from participating in the forthcoming evaluation. You may withdraw from the study at any time.

Benefits: This training will keep you abreast of the current knowledge of carbon literacy and climate change, enhancing your future employability.

Remuneration: You will not receive any compensation from this study. However, you will benefit from the knowledge of carbon literacy.

Study Expenses: There will be no financial obligation for your participation in this study.

Confidentiality: Your involvement is both confidential and anonymous. Your name will not be required on the assessment papers. The information you enter will be stored on a password-protected computer.

Results: The responses to your assessment will be processed using statistical methods, and the findings will be published in an online journal. I will send you text messages containing the website address where you can assess the published article.

Research-related Injury: The research environment is completely safe.

Preservation of all electronic and physical documents, including audio recordings: I will keep your responses (both hard and soft copies) in a safe and confidential place, and they will be disposed of after five years.

Contact individuals for any issues or inquiries: Please get in touch with the researcher at +27839915928, my supervisor at +27845055278, or the DUT-IREC Administrator at 031 373 2375. Complaints may be submitted to the Acting Director of Research and Postgraduate Support at researchdirector@dut.ac.za.

Appendix: B

CONSENT FORM

Title of Study: A Carbon Literacy for Green Innovation and Entrepreneurship Humanoid Robot-Assisted Digital Storytelling Model

Name of Researcher: George Essien

Agreement to join in the Research Study:

□ I confirm that researcher George Essien has told me about the nature, conduct, benefits, and hazards of this study - Research Ethics Clearance Number: IREC 217/24

□ I have received, read, and comprehended the information mentioned earlier (Participant information Letter) about the study.

□ I acknowledge that the study's findings, encompassing personal information such as my gender, age, date of birth, initials, and diagnosis, will be processed anonymously in a study report.

□ Given the research requirements, I agree that the researcher may process the data gathered during this investigation in a computerized system.

□ I may revoke my consent and participation in the study without consequence.

□ I have had enough chance to inquire and (of my own free will) declare myself ready to join the study.

☐ I acknowledge that substantial discoveries from this research, which may pertain to my involvement, will be accessible.

____________________	__________	______	_______________
Name of Participant	**Date**	**Time**	**Signature / Right Thumbprint**

I, George Essien, acknowledge that the participant mentioned above has been fully knowledgeable about the study's nature, conduct, and risks.

________________	__________	____________________
Name of Researcher	**Date**	**Signature**
________________	__________	____________________
Name of Witness (If applicable)	**Date**	**Signature**
______________	_________	__________________
Name of Legal Guardian (If applicable)	**Date**	**Signature**

Appendix: C

GATEKEEPER'S LETTER

15th July 2024

The Director

R&P Support

DUT

P. O. Box 1334

Durban

Request for Authorization to Perform Research

Dear Sir/Madam

I'm George Essien, a Durban University of Technology PhD candidate. The employment of a robot is part of the research I want to do for my doctoral thesis, which is called: A Carbon Literacy for Green Innovation and Entrepreneurship Humanoid Robot-Assisted Digital Storytelling Model.

I seek your consent to implement the project at the DUT MICT Seta 4IR Centre of Excellence computer laboratory.

I have sent a copy of my proposal, encompassing the data collecting instruments, consent and/or assent forms for the research procedure, and the approval letter from DUT-IREC. For any information, don't hesitate to contact me at +27839915928 or via email at 22290590@dut4life.ac.za. I appreciate your time and thought regarding this issue.

Yours sincerely,

George Essien

DUT

Appendix: D

Data Collection Tools

Pre-test

Carbon Literacy for Green Innovation and Entrepreneurship (CL4GIE) Training

This test measures your knowledge of CL4GIE before the training begins. This exercise is purely for academic purposes and is carried out by a PhD student at Durban University of Technology (DUT). The researcher is assuring you that your responses will be treated with confidentiality.

Circle the appropriate response for each of the questions below.

1. Which of the following gases constitute the main greenhouse gas?
   a) Oxygen
   b) Hydrogen
   c) Methane
   d) Carbon dioxide

2. The long-term warming of our environment and its resulting change in weather patterns is called ………………..
   a) global warming
   b) drought
   c) climate change
   d) heat waves

3. What term is given to a group of gases that trap heat and increase temperature on the Earth?
   a) Atmospheric gases
   b) Greenhouse gases
   c) Industrial gases
   d) Heat waves

4. Which activities will mitigate greenhouse gas emissions?
    a) Cutting down trees
    b) Burning of fossil fuels
    c) Burning of trees
    d) Use of electric cars
5. What activities are the primary contributors to greenhouse gas emissions?
    a) Transportation
    b) Agriculture
    c) Electricity generation
    d) Deforestation

Post-test One

Carbon Literacy for Green Innovation and Entrepreneurship (CL4GIE) Training

This questionnaire is meant to measure the knowledge you have acquired from the carbon literacy training and your level of satisfaction. This exercise is purely for academic purposes and is conducted by a PhD student at Durban University of Technology (DUT). The researcher guarantees that your replies will remain confidential.

Section - A: Knowledge Testing

Circle the appropriate response for each of the questions below.

1. The cognizance of the costs and effects of carbon dioxide on daily human activities is referred to as …………………………
    a) Climate change
    b) Carbon literacy
    c) Global warming
    d) Greenhouse gas emission

2. Which of the following activities will reduce greenhouse gas emissions?
    a) Use of fossil fuels
    b) Use of solar energy
    c) Indiscriminate cutting of trees
    d) Stop using renewable energy

3. Which of the following is not a consequence of greenhouse gas emissions?
    a) Flooding
    b) Heat waves
    c) Rising sea tidal waves
    d) Slight drop in temperature

4. The phenomena in which heat is retained in the Earth's atmosphere, increasing temperature, is referred to as ....
    a) Global warming
    b) Carbon literacy
    c) Climate change
    d) Greenhouse gases

5. Which of the following explains the greenhouse effect?
    a) Certain gases in the atmosphere are responsible for retaining heat and warming the planet.
    b) By exhaling gas, life on Earth contributes to the warming of the atmosphere.
    c) c) Differences in the amount of solar energy that the Earth gets are caused by the tilt of the Earth
    d) The sun is emitting a more significant amount of radiant energy over time.

Section B - Trainee Satisfaction Survey

Circle the appropriate response for each of the questions below.

1. How was the clarity of the presentation?
    a) Very clear
    b) Clear
    c) Moderately clear
    d) Slightly clear
    e) Not clear

2. Was the presentation interesting?
    a) Very interesting
    b) Interesting
    c) Moderately interesting
    d) Slightly interesting
    e) Not interesting

3. Did you feel motivated by the presentation?
    a) Highly motivated
    b) Motivated
    c) Moderately motivated
    d) Slightly motivated
    e) Not Motivated

4. How did you enjoy the presentation?
    a) Highly enjoyed
    b) Enjoyed
    c) Moderately enjoyed
    d) Slightly enjoyed
    e) Not enjoyed

5. To what extent are you satisfied with the carbon literacy training?
   a. Extremely satisfied
   b. Satisfied
   c. Moderately satisfied
   d. Slightly satisfied
   e. Not satisfied

Post-test Two

Carbon Literacy for Green Innovation and Entrepreneurship (CL4GIE) Training

This questionnaire is meant to measure the knowledge you have acquired from the carbon literacy training and your level of satisfaction. This activity is exclusively for academic reasons and is undertaken by a doctoral candidate at the Durban University of Technology (DUT). The researcher guarantees that your responses will be handled with secrecy.

<u>Section - A: Knowledge Testing</u>

1. The aggregate carbon emissions generated by an individual is …………
   a) Carbon cycle
   b) Carbon handprint
   c) Carbon footprint
   d) Carbon summary

2. What is the significance of being mindful of your carbon footprint's magnitude?
   a) Occasionally, it is challenging to locate shoes that fit correctly.
   b) If greenhouse gas emissions are not reduced, the Earth will persist in cooling.
   c) Greenhouse gases are diminishing in the Earth's atmosphere.
   d) The rise of greenhouse gases in the atmosphere is exacerbating global climate change.

3. The farmer's tractor contributes to the carbon footprint due to
    a) It is black
    b) It produces a sound
    c) It combusts fossil fuel while traversing the field.
    d) It is new

4. The primary human activity contributing to an individual's carbon footprint is
    a) Using solar and wind energy
    b) Human respiration and growth
    c) Usage of electric cars
    d) Using fossil fuels to produce energy

5. Which of these transportation options generates fewer greenhouse gases than the others?
    a) Walking
    b) Travelling by bus
    c) Travelling by car
    d) Travelling by train

Section - B: Trainee Satisfaction Survey

Circle the appropriate response for each of the questions below.

1. How was the clarity of the presentation?
    a. Very clear
    b. Clear
    c. Moderately clear
    d. Slightly clear
    e. Not clear

2. Was the presentation interesting?
    a. Very interesting
    b. Interesting
    c. Moderately interesting
    d. Slightly interesting
    e. Not interesting

3. Did you feel motivated by the presentation?
    a. Highly motivated
    b. Motivated
    c. Moderately motivated
    d. Slightly motivated
    e. Not Motivated

4. How did you enjoy the presentation?
    a. Highly enjoyed
    b. Enjoyed
    c. Moderately enjoyed
    d. Slightly enjoyed
    e. Not enjoyed

5. To what extent are you satisfied with the carbon literacy training?
    a. Extremely satisfied
    b. Satisfied
    c. Moderately satisfied
    d. Slightly satisfied
    e. Not satisfied

Appendix: E

TRREE Training Certificate

TRREE

Zertifikat

Certificat

Certificado

Certificate

Promouvoir les plus hauts standards éthiques dans la protection des participants à la recherche biomédicale
Promoting the highest ethical standards in the protection of biomedical research participants

Clinical Trials Centre
The University of Hong Kong

Certificat de formation - Training Certificate

Ce document atteste que - this document certifies that

George Essien

a complété avec succès - has successfully completed

Regulatory framework of South-Africa (2024)

du programme de formation TRREE en évaluation éthique de la recherche
of the TRREE training programme in research ethics evaluation

Release Date: 2024/07/17

Professeur Dominique Sprumont
Coordinateur TRREE Coordinator

APPROVED BY SIWF FMH ISFM

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[REV : 20220217]

Appendix: F

Ethics Clearance

Institutional Research Ethics Committee
Research and Postgraduate Support Directorate
2nd Floor, Berwyn Court
Gate 1, Steve Biko Campus
Durban University of Technology

P O Box 1334, Durban, South Africa, 4001

Tel: 031 373 2375
Email: lavishad@dut.ac.za
http://www.dut.ac.za/research/institutional_research_ethics

www.dut.ac.za

28 October 2024

Mr G Essien
Department of Information Technology
Faculty of Accounting and Informatics
Durban University of Technology

Dear Mr Essien

A Carbon Literacy for Green Innovation and Entrepreneurship Humanoid Robot-Assisted Digital Storytelling Model
Ethics Clearance Number: IREC 217/24

The DUT-Institutional Research Ethics Committee acknowledges receipt of your notification regarding the piloting of your data collection tool.

Kindly ensure that participants used for the pilot study are not part of the main study.

In addition, the DUT-IREC acknowledges receipt of your gatekeeper permission letter.

Please note that FULL APPROVAL is granted to your research proposal. You may proceed with data collection.

Any adverse events [serious or minor] which occur in connection with this study and/or which may alter its ethical consideration must be reported to the DUT-IREC according to the DUT-IREC SOP's.

Please note that any deviations from the approved proposal require the approval of the DUT-IREC as outlined in the DUT-IREC SOP's.

It is compulsory for a student or researcher to apply for recertification on an annual basis. The failure to do so will result in withdrawal of ethics clearance. It is the responsibility of the researcher and the supervisor to apply for recertification.

Please note that you are required to submit a Notification of Completion of Study form together with an abstract to the DUT-IREC office on completion of your study.

Yours Sincerely

Professor P Mashau
Chairperson: DUT-IREC

Appendix: G

Reviewer's Questionnaire

The following table contains questions regarding the method adopted to develop a model for robot storytelling instruction. Kindly peruse the attached document that contains the model and respond to the questions in the table below. Please tick the appropriate response. This review is intended solely for scholarly purposes and has no other objective. Thank you for your attention and assistance.

Table 1: Expert review questionnaire

S/N	**Statement**	**Responses**				
		Strongly Agree	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
1	The elements or phases of the model are adequate for instruction delivery.					
2	All elements or phases are relevant to robot storytelling creation.					
3	The meaning of the model elements is apparent.					
4	The method used to develop the instructional model is appropriate.					
5	The method carried out by the researcher justifies the phases or elements of the instructional model.					
Comments/Suggestions						

Appendix: H

T-distribution Table (T Table, 2025)

t Table

cum. prob	$t_{.50}$	$t_{.75}$	$t_{.80}$	$t_{.85}$	$t_{.90}$	$t_{.95}$	$t_{.975}$	$t_{.99}$	$t_{.995}$	$t_{.999}$	$t_{.9995}$
one-tail	**0.50**	**0.25**	**0.20**	**0.15**	**0.10**	**0.05**	**0.025**	**0.01**	**0.005**	**0.001**	**0.0005**
two-tails	**1.00**	**0.50**	**0.40**	**0.30**	**0.20**	**0.10**	**0.05**	**0.02**	**0.01**	**0.002**	**0.001**
df											
1	0.000	1.000	1.376	1.963	3.078	6.314	12.71	31.82	63.66	318.31	636.62
2	0.000	0.816	1.061	1.386	1.886	2.920	4.303	6.965	9.925	22.327	31.599
3	0.000	0.765	0.978	1.250	1.638	2.353	3.182	4.541	5.841	10.215	12.924
4	0.000	0.741	0.941	1.190	1.533	2.132	2.776	3.747	4.604	7.173	8.610
5	0.000	0.727	0.920	1.156	1.476	2.015	2.571	3.365	4.032	5.893	6.869
6	0.000	0.718	0.906	1.134	1.440	1.943	2.447	3.143	3.707	5.208	5.959
7	0.000	0.711	0.896	1.119	1.415	1.895	2.365	2.998	3.499	4.785	5.408
8	0.000	0.706	0.889	1.108	1.397	1.860	2.306	2.896	3.355	4.501	5.041
9	0.000	0.703	0.883	1.100	1.383	1.833	2.262	2.821	3.250	4.297	4.781
10	0.000	0.700	0.879	1.093	1.372	1.812	2.228	2.764	3.169	4.144	4.587
11	0.000	0.697	0.876	1.088	1.363	1.796	2.201	2.718	3.106	4.025	4.437
12	0.000	0.695	0.873	1.083	1.356	1.782	2.179	2.681	3.055	3.930	4.318
13	0.000	0.694	0.870	1.079	1.350	1.771	2.160	2.650	3.012	3.852	4.221
14	0.000	0.692	0.868	1.076	1.345	1.761	2.145	2.624	2.977	3.787	4.140
15	0.000	0.691	0.866	1.074	1.341	1.753	2.131	2.602	2.947	3.733	4.073
16	0.000	0.690	0.865	1.071	1.337	1.746	2.120	2.583	2.921	3.686	4.015
17	0.000	0.689	0.863	1.069	1.333	1.740	2.110	2.567	2.898	3.646	3.965
18	0.000	0.688	0.862	1.067	1.330	1.734	2.101	2.552	2.878	3.610	3.922
19	0.000	0.688	0.861	1.066	1.328	1.729	2.093	2.539	2.861	3.579	3.883
20	0.000	0.687	0.860	1.064	1.325	1.725	2.086	2.528	2.845	3.552	3.850
21	0.000	0.686	0.859	1.063	1.323	1.721	2.080	2.518	2.831	3.527	3.819
22	0.000	0.686	0.858	1.061	1.321	1.717	2.074	2.508	2.819	3.505	3.792
23	0.000	0.685	0.858	1.060	1.319	1.714	2.069	2.500	2.807	3.485	3.768
24	0.000	0.685	0.857	1.059	1.318	1.711	2.064	2.492	2.797	3.467	3.745
25	0.000	0.684	0.856	1.058	1.316	1.708	2.060	2.485	2.787	3.450	3.725
26	0.000	0.684	0.856	1.058	1.315	1.706	2.056	2.479	2.779	3.435	3.707
27	0.000	0.684	0.855	1.057	1.314	1.703	2.052	2.473	2.771	3.421	3.690
28	0.000	0.683	0.855	1.056	1.313	1.701	2.048	2.467	2.763	3.408	3.674
29	0.000	0.683	0.854	1.055	1.311	1.699	2.045	2.462	2.756	3.396	3.659
30	0.000	0.683	0.854	1.055	1.310	1.697	2.042	2.457	2.750	3.385	3.646
40	0.000	0.681	0.851	1.050	1.303	1.684	2.021	2.423	2.704	3.307	3.551
60	0.000	0.679	0.848	1.045	1.296	1.671	2.000	2.390	2.660	3.232	3.460
80	0.000	0.678	0.846	1.043	1.292	1.664	1.990	2.374	2.639	3.195	3.416
100	0.000	0.677	0.845	1.042	1.290	1.660	1.984	2.364	2.626	3.174	3.390
1000	0.000	0.675	0.842	1.037	1.282	1.646	1.962	2.330	2.581	3.098	3.300
z	0.000	0.674	0.842	1.036	1.282	1.645	1.960	2.326	2.576	3.090	3.291
	0%	50%	60%	70%	80%	90%	95%	98%	99%	99.8%	99.9%
	Confidence Level										