

Improving Undergraduate Students' Understanding of Carbon Literacy through the Use of Robot-Assisted Digital Storytelling



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ABSTRACT

Understanding climate change, the human activities that contribute to it, and the ability to reduce or eliminate those activities are key aspects of carbon literacy. Carbon dioxide and other greenhouse gases released into the atmosphere are the main drivers of climate change. Climate change has brought several effects, including drought, hurricanes, rising sea levels, flooding, and high temperatures worldwide. Robot-assisted digital storytelling is a digital storytelling method that uses social robots to tell stories to listeners. It is an efficient instructional delivery method that can be used to teach students in classrooms. This study uses robot-assisted digital storytelling to deliver carbon literacy lessons to selected undergraduate students and improve their understanding of the concept. The study administered a pre-test and a post-test and compared the results to determine whether robot storytelling enhanced students' understanding of carbon literacy. The study also used a narrated PowerPoint presentation to provide identical instructions on carbon literacy and compared it to robot-assisted digital storytelling. The study found that students' understanding of carbon literacy was enhanced through a narrated PowerPoint presentation and robot-assisted digital storytelling. However, robot-assisted digital storytelling yielded superior learning effects compared to a narrated PowerPoint presentation. Based on the findings, this study suggests using robot-assisted digital storytelling to teach carbon literacy and raise awareness of climate change in schools.

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INTRODUCTION

According to Tadesse and Dereje, climate change is a sustained and substantial alteration in the typical patterns of a region's average weather over an appropriately extended period. Greenhouse gases (GHGs) released into the atmosphere are the leading cause of climate change.¹ These gases include carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O). Human activities cause the emission of greenhouse gases into the atmosphere. Burning fossil fuels such as petroleum, coal, and natural gas is an example of human activity that emits greenhouse gases. Deforestation and agriculture are also human activities that contribute to atmospheric greenhouse gas emissions.² Greenhouse gases absorb high

¹ Gezu Tadesse and Moges Dereje, "Impact of Climate Change on Smallholder Dairy Production and Coping Mechanism in Sub-Saharan Africa-Review," *Climate Change* 4, no. 15 (2018): 299–313.

² Tadesse and Dereje, "Impact of Climate Change on Smallholder Dairy Production and Coping Mechanism in Sub-Saharan Africa-Review."

amounts of heat into the Earth's atmosphere, which, in turn, causes changes in weather conditions.³ These changes include drought, hurricanes, rising sea levels, flooding, and high temperatures across different regions of the world. Carbon dioxide is the dominant component of Greenhouse gases, accounting for almost 75% of global emissions.⁴

Governments and organizations worldwide believe that educating people about the impact of carbon dioxide on climate change will be an effective way to tackle the problem. This education led to the term carbon literacy. Carbon Literacy is the awareness of climate change and its impact on humanity's everyday actions.⁵ Howel also defined carbon literacy as an individual's ability to obtain, understand, and evaluate the relevant information necessary to make decisions with an awareness of the likely consequences of greenhouse gas emissions.⁶ Carbon literacy enables individuals and organizations to learn the best practices to prevent the adverse effects of climate change.

Robot-assisted digital storytelling is an effective teaching and learning technique that can be utilized to implement carbon literacy education. According to Essien and Parbanath, robot storytelling is mainly used to impart knowledge to pupils and students in educational institutions.⁷ In addition, robot storytelling positively impacts teaching and learning at all levels of the academic ladder. Several researchers have used robot storytelling to deliver instructions to learners, achieving positive learning outcomes. For example, Chang et al. found that robot storytelling improves students' learning achievement and critical thinking, following research they conducted using robot storytelling to teach lesson plan design in a teaching hospital.⁸ Liang and Hwang also used robot storytelling to teach English as a foreign language to senior high school students.⁹ The study's results revealed that robot storytelling enhanced the students' English-speaking ability and improved their narrative engagement and communication tendencies. Tengler et al. conducted a study to investigate how robots improve computational thinking skills by designing and building an interactive story using the robot Ozobot.¹⁰ The results show that combining educational robots and storytelling is a promising approach to promoting computational thinking. Iio et al. used a social robot to teach English to nine Japanese adults. In this robot-assisted language-learning study, the researchers administered a pre-test to participants before conducting the robot-assisted language-learning activities.¹¹ After the participants completed the activities, they also received a post-test. The results of the two tests indicated that robot-assisted storytelling language learning has improved participants' speaking abilities.

This study used robot-assisted digital storytelling to deliver carbon literacy instruction to selected students at the Durban University of Technology. The study aims to enhance the knowledge of carbon literacy and to raise awareness of the consequences of greenhouse gas emissions. Like robot-assisted digital storytelling, the study also used narrated PowerPoint to deliver carbon literacy lessons to students. This second presentation enabled the study to compare the results of the two presentation modes.

The following research questions guided the study.

Research question 1: Will robot-assisted digital storytelling improve students' learning outcomes?

³ H. Ritchie and M. Roser, "CO₂ and Other Greenhouse Gas Emissions," Our world is in data, 2017, Evidence of Global Warming in VA Case Study – Supplemental Document 2.pdf.

⁴ Muhammad Nda et al., "A Review on the Causes, Effects and Mitigation of Climate Changes on the Environmental Aspects," *International Journal of Integrated Engineering* 10, no. 4 (August 1, 2018), <https://doi.org/10.30880/ijie.2018.10.04.027>.

⁵ Z. Handwiki, "Carbon Literacy," 2022, https://handwiki.org/wiki/Earth:Carbon_literacy.

⁶ Rachel A. Howell, "Carbon Management at the Household Level: A Definition of Carbon Literacy and Three Mechanisms That Increase It," *Carbon Management* 9, no. 1 (January 2, 2018): 25–35, <https://doi.org/10.1080/17583004.2017.1409045>.

⁷ George Essien and Steven S Parbanath, "Exploring the World of Robot-Assisted Digital Storytelling: Trends, Models, and Educational Implications," *Journal of Information Technology Education: Research* 23 (2024): 027, <https://doi.org/10.28945/5378>.

⁸ Yu-Chen Kuo and Yen-Cheng Chang, "Adaptive Teaching of Flipped Classroom Combined with Concept Map Learning Diagnosis—an Example of Programming Design Course," *Education and Information Technologies* 28, no. 7 (July 27, 2023): 8665–89, <https://doi.org/10.1007/s10639-022-11540-4>.

⁹ Jia-Cing Liang and Gwo-Jen Hwang, "A Robot-Based Digital Storytelling Approach to Enhancing EFL Learners' Multimodal Storytelling Ability and Narrative Engagement," *Computers & Education* 201 (August 2023): 104827, <https://doi.org/10.1016/j.compedu.2023.104827>.

¹⁰ Karin Tengler, Oliver Kastner-Hauler, and Barbara Sabitzer, "Enhancing Computational Thinking Skills Using Robots and Digital Storytelling," in *Proceedings of the 13th International Conference on Computer Supported Education* (SCITEPRESS - Science and Technology Publications, 2021), 157–64, <https://doi.org/10.5220/0010477001570164>.

¹¹ Takamasa Iio et al., "Improvement of Japanese Adults' English Speaking Skills via Experiences Speaking to a Robot," *Journal of Computer Assisted Learning* 35, no. 2 (April 6, 2019): 228–45, <https://doi.org/10.1111/jcal.12325>.

Research question 2: Will narrated PowerPoint presentations improve students' learning outcomes?

Research question 3: Will robot-assisted digital storytelling improve learning outcomes better than a narrated PowerPoint presentation on carbon literacy?

LITERATURE REVIEW

Researchers in digital storytelling (DST) have offered many definitions of the field. Robin defined DST as the art of merging storytelling with a combination of digital media elements, including text, photographs, recorded audio narration, music, and video.¹² According to Robin's paper, DST consists of short stories that span 2 to 10 minutes and utilize various digital media elements.¹³ Robin and McNeil also described DST as a movie-making technique that combines digital artefacts to produce short movies, including photos, text, video clips, animation, and music.¹⁴ 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.¹⁵ In addition, Smeda *et al.* defined DST as the use of various multimedia tools and components, such as animation, audio, video, and graphics, to tell a tale.¹⁶ Rossiter and Garcier provide an additional definition of DST, arguing that it comprises brief vignettes that integrate storytelling through multimedia artefacts such as photographs, audio, and video materials.¹⁷ Sage *et al.* described DST as conveying a narrative through various digital media, including audio, video, art, graphics, images, and text.¹⁸ All the definitions described above revolve around the same idea: using one or more multimedia elements to tell a story, without taking into account 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, according to McLellan.¹⁹ Dana Atchley, a performer who tells stories, began incorporating multimedia as a prop and adopted various storytelling approaches. According to McLellan, he used software tools to build and narrate stories through cinema, video, music, and photography, and to fashion a new show for each performance.²⁰ Atchley's storytelling performance centred on telling stories over a campfire.²¹ 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 into an emotionally powerful tapestry of life.²² Atchley and Joe Lambert spent the 1990s exploring their mutual interest in digital stories.²³ 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.²⁴ The

¹² Bernard R Robin, "The Power of Digital Storytelling to Support Teaching and Learning," *Digital Education Review*, no. 30 (2016): 17–29.

¹³ Robin, "The Power of Digital Storytelling to Support Teaching and Learning."

¹⁴ Bernard R. Robin and Sara G. McNeil, "Digital Storytelling," in *The International Encyclopedia of Media Literacy* (Wiley, 2019), 1–8, <https://doi.org/10.1002/9781118978238.ieml0056>.

¹⁵ Hilary McLellan, "Digital Storytelling in Higher Education," *Journal of Computing in Higher Education* 19, no. 1 (September 2007): 65–79, <https://doi.org/10.1007/BF03033420>.

¹⁶ Najat Smeda, Eva Dakich, and Nalin Sharda, "The Effectiveness of Digital Storytelling in the Classrooms: A Comprehensive Study," *Smart Learning Environments* 1, no. 1 (December 3, 2014): 6, <https://doi.org/10.1186/s40561-014-0006-3>.

¹⁷ Marsha Rossiter and Penny A. Garcia, "Digital Storytelling: A New Player on the Narrative Field," *New Directions for Adult and Continuing Education* 2010, no. 126 (June 15, 2010): 37–48, <https://doi.org/10.1002/ace.370>.

¹⁸ L. Vygotsky and M Cole, "Lev Vygotsky: Learning and Social Constructivism," *Learning Theories for Early Years Practice. UK: SAGE Publications Inc*, 2018, 68–73.

¹⁹ McLellan, "Digital Storytelling in Higher Education."

²⁰ McLellan, "Digital Storytelling in Higher Education."

²¹ McLellan, "Digital Storytelling in Higher Education."

²² McLellan, "Digital Storytelling in Higher Education."

²³ McLellan, "Digital Storytelling in Higher Education."

²⁴ McLellan, "Digital Storytelling in Higher Education."

CDS is the most prominent global organization that promotes digital storytelling. It provides training to individuals on how to create short media pieces by combining digital image and video editing tools.²⁵

According to Robin, digital storytelling can be categorized into three main types: personal narratives, historical events, and instructional or enlightening stories.²⁶ Personal narratives encompass people's life experiences, including travel, tourism, education, marriage, festivals, and the working environment. Historical events are presented through digital storytelling that highlights key moments. 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, an institution, or an organization. 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 through university. Instructors at various academic levels are using 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, people use digital storytelling to present new material, facilitate discussion, and make abstract content more understandable.²⁷ Students use digital storytelling to prepare their work, thus becoming more creative and skilled in expressing their opinions.²⁸ Moreover, online digital storytelling allows students to showcase their work digitally and exchange ideas with their peers.²⁹ Digital storytelling is used in educational institutions, communities, and organizations to educate members about pertinent issues, such as climate change.³⁰

Businesses use digital storytelling to promote their products to potential customers through social media.³¹ Numerous organizations leverage internet platforms, such as Facebook, X, and Instagram, to market their products and services to prospective customers.³² Digital storytelling, typically in the form of short videos, is prevalent on these social media platforms.³³

Digital storytelling is used in healthcare delivery to share vital health information and educate individuals about various diseases. Hospitals use digital storytelling to provide electronic information on numerous diseases and their associated symptoms. For instance, hospitals create videos featuring people with diseases such as malaria and tuberculosis, along with their 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.³⁴

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 software, computer-based software, and mobile device software. Robot-assisted platforms are social robots that narrate stories to people. Social robots are autonomous entities that emulate human thought and behaviour, allowing unrestricted interaction with people.³⁵ Social robots can be humanoid

²⁵ McLellan, "Digital Storytelling in Higher Education."

²⁶ B. Robin, "The Educational Uses of Digital Storytelling," Society for Information Technology & Teacher Education International Conference, March 2006, Association for the Advancement of Computing in Education (AACE). The Educational Uses of Digital Storytelling - Learning & Technology Library (LearnTechLib).

²⁷ Robin and McNeil, "Digital Storytelling."

²⁸ I Gusti Agung Paramitha Eka Putri, "Critical Environmental Education in Tertiary English Language Teaching (ELT): A Collaborative Digital Storytelling Project," *Indonesian Journal of Applied Linguistics* 8, no. 2 (September 30, 2018), <https://doi.org/10.17509/ijal.v8i2.13280>.

²⁹ Eleni Papadimitriou et al., "Digital Storytelling in Kindergarten: An Alternative Tool in Children's Way of Expression.," *Mediterranean Journal of Social Sciences*, October 1, 2013, <https://doi.org/10.5901/mjss.2013.v4n11p389>.

³⁰ Daniel Otto, "Lived Experience of Climate Change - a Digital Storytelling Approach," *International Journal of Global Warming* 12, no. 3/4 (2017): 331, <https://doi.org/10.1504/IJGW.2017.084784>.

³¹ Keshia K Coker, Richard L Flight, and Dominic M Baima, "Skip It or View It: The Role of Video Storytelling in Social Media Marketing," *Marketing Management Journal* 27, no. 2 (2017).

³² Amita Charan and Ekta Bansal, "Impact of Digital Marketing through Facebook Vs. Twitter : A Comparative Study on Indian Consumers," *Review of Professional Management- A Journal of New Delhi Institute of Management* 14, no. 2 (December 1, 2016): 34, <https://doi.org/10.20968/rpm/2016/v14/i2/130975>.

³³ Coker, Flight, and Baima, "Skip It or View It: The Role of Video Storytelling in Social Media Marketing."

³⁴ Robin, "The Power of Digital Storytelling to Support Teaching and Learning."

³⁵ Yumi Lee, Dayoung Lee, and Hyun Ju Hong, "Gender-Based Multilevel Analysis of Influential Factors for Suicide Attempts among at-Risk Non-Referral Adolescents in Korea," *Clinical Psychopharmacology and Neuroscience* 18, no. 1 (2020): 116.

or animaloid.³⁶ Examples of social robots include Pepper, Nao, Asimo, Kebbi Air, Sota, and Haru.³⁷ This paper used a Nao robot to impart carbon literacy knowledge to selected undergraduate students.

METHODOLOGY

This study used an experimental design to deliver carbon literacy instruction to selected students at Durban University of Technology, South Africa. Experimental research is a study that tests an idea, practice, or procedure to determine whether it affects the outcome or the dependent variable.³⁸ Experimental research compares two or more groups on one or more measures.³⁹ The participants are in an advanced diploma program in software engineering. Sixteen students opted to participate after the class was briefed on the study's purpose. The participants are in the twenty-to-thirty age range, consisting of ten males and six females. The selected students were randomly assigned to two groups: the experimental and the control. The experimental group was taught using robot-assisted digital storytelling, and the control group received their lesson through a narrated PowerPoint presentation.

Design and delivery of robot-assisted digital storytelling

This study followed a custom-made instructional model for designing and delivering robot-assisted digital storytelling. The proposed model has six elements: storytelling requirements, preparation, programming, testing, delivery, and assessment (see Figure 1). The following is a brief discussion of what is done in each phase of the model.

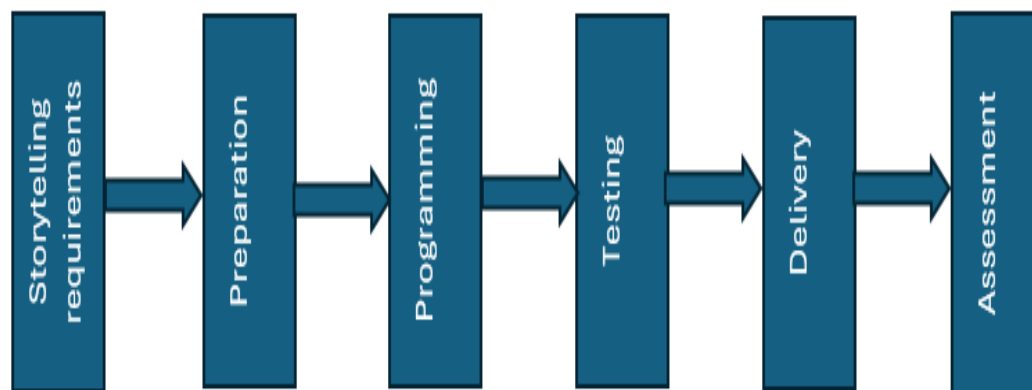


Figure 1: The proposed model for robot-assisted digital storytelling instruction

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 provided by Aldebaran Robotics.⁴⁰ Nao has 25 degrees of freedom and is capable of walking

³⁶ Siti Sendari, Hakkun Elmunsyah, and Yogi Dwi Mahandi, "Six-Legged Animaloid Robot as a Trainer for Robotic Course," 2015, <https://doi.org/10.2991/ictvet-14.2015.44>.

³⁷ D. Allan and C. Bartneck, "Aldebaran Again-Is This the End of Pepper?," 2022, HRI-Podcast-Episode-024-Aldebaran-Again-Transcript.pdf; KISUNG Seo and ALDEBARAN Robotics, "Using Nao: Introduction to Interactive Humanoid Robots," *Aldebaran Robotics*, 2013; Masato Hirose and Kenichi Ogawa, "Honda Humanoid Robots Development," *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 365, no. 1850 (January 15, 2007): 11–19, <https://doi.org/10.1098/rsta.2006.1917>; Jun Chen Hsieh and Ju Seong Lee, "Digital Storytelling Outcomes, Emotions, Grit, and Perceptions among EFL Middle School Learners: Robot-Assisted versus PowerPoint-Assisted Presentations," *Computer Assisted Language Learning* 36, no. 5–6 (July 4, 2023): 1088–1115, <https://doi.org/10.1080/09588221.2021.1969410>; Bruce Henning, "Stretching the Scope of Salvation in Matthew: The Significance of the Great Peter's Failings," *New Testament Studies* 68, no. 4 (October 8, 2022): 474–86, <https://doi.org/10.1017/S0028688522000145>; Alejandro López-Valenciano et al., "Epidemiology of Injuries in Professional Football: A Systematic Review and Meta-Analysis," *British Journal of Sports Medicine* 54, no. 12 (June 2020): 711–18, <https://doi.org/10.1136/bjsports-2018-099577>.

³⁸ Vicki Plano-Clark and John Creswell, *Understanding Research: A Consumer's Guide* (Boston: Pearson, 2015).

³⁹ Muhammad Affan Ramadhana and Deis Kondo Allo, "Experimental Research in English Language Teaching: A Peek from Undergraduate Students' Theses," *Jurnal Studi Guru Dan Pembelajaran* 4, no. 1 (March 23, 2021): 32–38, <https://doi.org/10.30605/jsgp.4.1.2021.474>.

⁴⁰ Syamimi Shamsuddin et al., "Humanoid Robot NAO: Review of Control and Motion Exploration," in *2011 IEEE International Conference on Control System, Computing and Engineering* (IEEE, 2011), 511–16, <https://doi.org/10.1109/ICCSCE.2011.6190579>.

bipedally.⁴¹ It has one of its processors mounted on its chest, which can read all sensors in 8ms.⁴² The Nao robot has its central processing unit in its head, running the Gentoo Linux operating system.⁴³ Nao is 57.3cm tall, 27.3cm wide, and weighs 5.6kg. The body of Nao is made of plastic and features a 21.6V 2Ah lithium-ion battery that lasts for 90 minutes.⁴⁴ Nao can be connected to a computer via cable or wireless. Choregraphe, an easy-to-use graphical user interface programming software, is used to create applications that control Nao's operations. Nao has four directional microphones, two speakers, and two cameras. In addition to the Nao robot, the study selected 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 an architecture for a robot storytelling system to guide its development. The system architecture specifies the components of a system and the communication between them.⁴⁵

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 2.

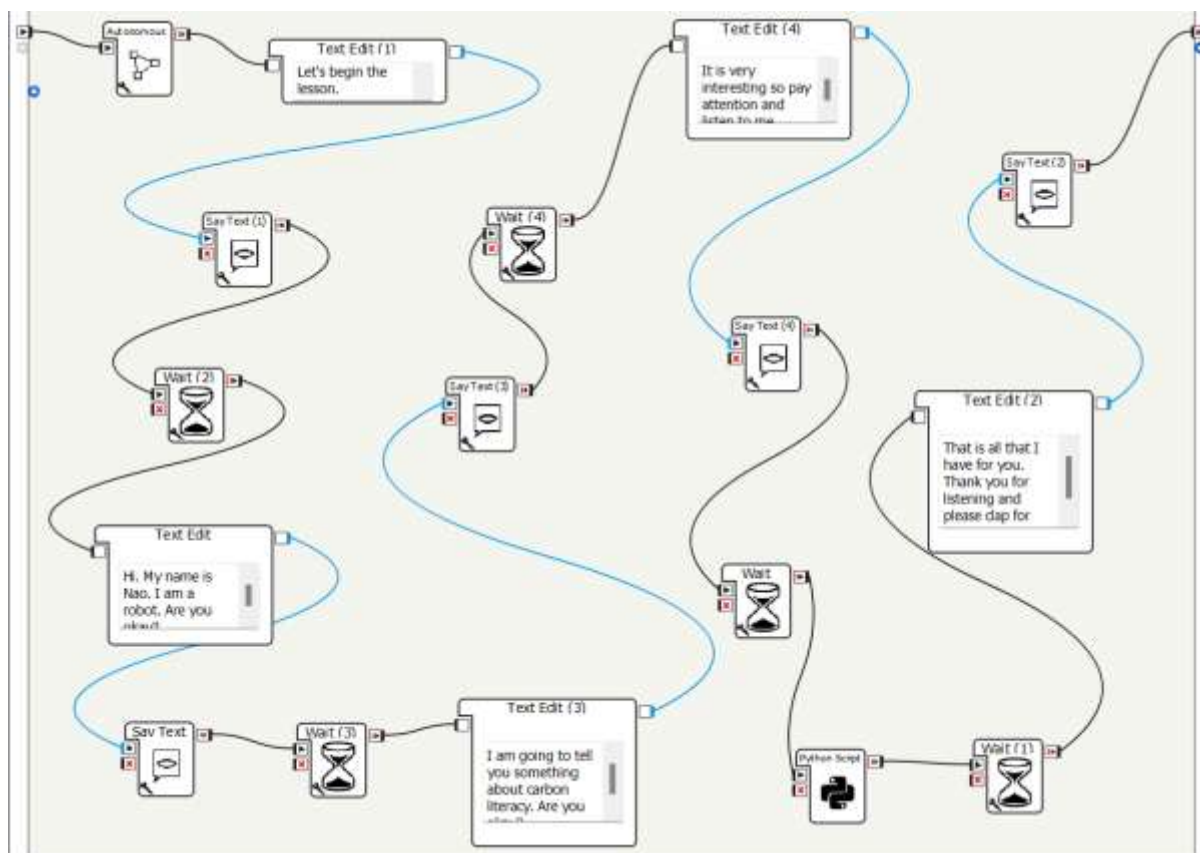


Figure 2: Coding box diagram of Nao Robot on carbon literacy instruction (Choregraphe application: Courtesy SoftBank Robotics Documentation)

The coding box diagram in Figure 2 consists of one autonomous box, five Text edit boxes, five Say text boxes, five Wait boxes, and one Python script box.

⁴¹ Tobias Deutsch et al., "Cognitive Decision Unit Applied to Autonomous Biped Robot NAO," in *2011 9th IEEE International Conference on Industrial Informatics* (IEEE, 2011), 75–80, <https://doi.org/10.1109/INDIN.2011.6034840>.

⁴² Deutsch et al., "Cognitive Decision Unit Applied to Autonomous Biped Robot NAO."

⁴³ Deutsch et al., "Cognitive Decision Unit Applied to Autonomous Biped Robot NAO."

⁴⁴ Seo and Robotics, "Using Nao: Introduction to Interactive Humanoid Robots."

⁴⁵ D. C. Luckham, J. Vera, and S. Meldal, "Three Concepts of System Architecture," *Computer Systems Laboratory, Stanford University*, 1995.

Testing: In this phase, the study played Nao's presentation to a selected audience. The audience was asked to provide their opinion of Nao's presentation. The feedback was used to amend the code to get the final code.

Delivery: The participants were seated in the DUT MICT Seta 4IR Centre of Excellence Computer Laboratory on the day of the lesson. The participants were then given letters containing information on the lesson's purpose, procedure outline, benefits, and the process for storing and disseminating the study results. They were then briefed on the study's purpose. The instructor gave the participants consent forms to fill out and sign. The participants wrote a pre-test to enable the instructor to assess their prior knowledge of carbon literacy. After that exercise, the instructor switched on the Nao robot. The robot welcomed the participants, introduced itself, and explained the purpose of the training. The robot then began to lecture the participants on carbon literacy (see Figure 3). The robot storytelling presentation was repeated following the participants' request. The robot storytelling presentation lasted about twenty minutes.

Assessment: After the robot presentation, 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. These multiple-choice questions aim to assess the students' carbon literacy knowledge gained from the robot presentation. Participants completed questionnaires, enabling the study to assess their satisfaction with the robot presentation.



Figure 3: The experimental group is listening to the presentation by the Nao robot.

Narrated PowerPoint presentation

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

On the day of the lesson, participants were seated in the DUT MICT Seta 4IR Centre of Excellence Computer Laboratory. The participants were then given letters containing information on the training's purpose, a procedure outline, benefits, and the process for storing and disseminating the study results. The instructor informed the participants about the study's purpose and provided consent forms for them to complete and sign. They were also given a pre-test of multiple-choice questions to write. This pre-test enabled the study to assess participants' carbon literacy before the lesson delivery. After the pre-test, the instructor opened the narrated PowerPoint presentation while the participants were seated and listened to it. The narrated PowerPoint presentation, like the robot storytelling presentation, was repeated after the first presentation. The narrated PowerPoint presentation also lasted about twenty minutes. After the presentation, the participants had a five-minute break to prepare for the post-test. After the break, the participants wrote multiple-choice questions on carbon literacy. This test assessed participants' carbon literacy acquired from the presentation. Participants completed questionnaires, allowing the instructor to gauge their satisfaction with the narrated PowerPoint presentation.

PRESENTATION OF RESULTS AND DISCUSSIONS

Table 1 presents the evaluation outcomes of the experimental and control groups' pre-test and post-test results. Before the start of the course, the study used pre-tests to gauge participants' levels of carbon literacy. The study conducted post-tests after the presentations and based on the pre-test and post-test outcomes, assessed the effects of narrated PowerPoint training and robot storytelling on participants' carbon literacy knowledge. There are eight participants in each group.

Table 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 |

Paired sample t-statistics of the experimental group's pre-test and post-test scores

Table 2 shows the pre-test scores (x), the post-test scores (y), and the differences between the corresponding scores (d). Table 2 also displays the difference values, less the mean of the difference values ($d - \bar{d}$). The last column in Table 2 is the square of the difference values minus the mean of the difference values. The computations that follow Table 2 show the mean values of the pre-test scores, post-test results, and the score difference values. These computations are followed by the standard deviation of the difference values, the standard error of the mean of the difference values, and the t-test statistic needed to test the hypotheses in this section.

Table 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, $S_d = \sqrt{\frac{\sum (d - \bar{d})^2}{n-1}}$

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

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

$$S_d = \sqrt{0.6964285714}$$

$$S_d = 0.835$$

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

$$T\text{-test statistic, } t = \frac{1.875}{0.295}$$

$$T\text{-test statistic, } t = 6.356$$

Discussion: The mean values of the pre-test and post-test clearly show that the post-test improved over the pre-test. However, the t-test statistic will substantiate this assertion. The following hypothesis was

used to test the t-test statistic of the experimental group scores at a 95% confidence level and 7 (n-1) degrees of freedom.

Null hypothesis (H₀): The statistical mean values of the pre-test and post-test data are identical.

Alternative hypothesis (H₁): 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 the appendix shows that the critical t-value is 2.365 at a 95% confidence level and 7 degrees of freedom. The study therefore rejects the null hypothesis and accepts the alternative hypothesis because the computed t value exceeds the t value from the t-distribution table. Hence, the two means differ, and therefore, the robot storytelling presentation positively impacted the participants' learning outcomes.

Paired sample t-statistics of the control group scores

Table 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 3. The 6th column in Table 3 shows the squares of the computed values in the 5th column. Following Table 3 are computations of the mean of the pre-test scores, the mean of the post-test scores, the mean of the differences, the standard deviation of the differences, the standard error of the differences, and finally, the t-test statistic value.

Table 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, $\bar{x} = \frac{\sum x}{n}$

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

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, $S_d = \sqrt{\frac{\sum(a - \bar{a})^2}{n-1}}$

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

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

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

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

Discussion: A comparison of the pre-test and post-test scores shows that the narrated PowerPoint presentation improved learning outcomes. However, this assumption can only be confirmed by comparing the pre-test and post-test means using t-test statistics. 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.

Null hypothesis (H₀): The statistical mean values of the pre-test and post-test data are identical.

Alternative hypothesis (H₁): 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 the appendix, when used to determine the critical t-value, yields 2.365 at a 95% confidence level with 7 degrees of freedom. Therefore, the alternative hypothesis is accepted, and the null hypothesis is rejected since the computed t-value is higher than the corresponding t-value from the t-distribution table in the appendix. Rejecting the null hypothesis indicates that the two means differ; therefore, the narrated PowerPoint presentation enhanced participants' learning outcomes.

Independent Samples T-Test of Experimental and Control Group Post-test Scores

Unlike 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.

Table 4 presents the post-test scores for the experimental and control groups, including the mean differences and scores. The Table also shows the square of the differences between the scores and the mean scores, which were used to calculate the standard deviations of the two groups' scores. There are eight scores in each group. The computation following Table 4 shows the mean scores for both groups. In addition, the calculation shows the standard deviations of the two groups and, consequently, the independent t-test statistics

Table 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, $S_x = \sqrt{\frac{\sum (X - \bar{X})^2}{n-1}}$

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

$$S_x = 0.463$$

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

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

$$S_y = 0.535$$

$$\text{Independent t-test, } t = \frac{\bar{X} - \bar{Y}}{\sqrt{\left(\frac{S_x^2}{n_1}\right) + \left(\frac{S_y^2}{n_2}\right)}}$$

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

$$\text{Independent t-test } t = 2.998$$

Degrees of freedom, $df = n_1 + n_2 - 2 = 8+8-2 = 14$

Confidence level = 95%

Discussion: The scores revealed that the experimental and control groups performed better on the post-tests. However, an independent t-test was used to compare the two groups' means to determine whether they performed equally. The following hypothesis was set to test the equality of the two groups' means.

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

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

According to the computation in this section, the mean value of the robot storytelling outcomes is 4.75, which is higher than the mean of 4.00 from the narrated PowerPoint presentation results. The calculation produced a t-test value of 2.998. From the t-distribution table, the critical t-value at a 95% confidence level and 14 degrees of freedom is 2.145. The calculated value exceeds the critical value obtained from the t-distribution. The comparison of these two t-values indicates that the study rejects the null hypothesis. This hypothesis test accepts the alternative hypothesis, indicating that the two mean scores are not identical. Therefore, the robot storytelling presentation produced a better learning experience than the narrated PowerPoint presentation.

| 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 | | | | | | | | | | |

Figure 4: T-table (Table Courtesy www.sjsu.edu)

Summary of the Discussion

This discussion provides the following responses to the research questions. Robot-assisted digital storytelling improved students' learning outcomes on carbon literacy. The improved student performance, as indicated by post-test results compared to pre-test, may be due to students' enjoyment of the robot's presentation, particularly its gestures. This assertion is confirmed by a similar study by Velentza *et al.*, which used the Nao robot to teach students about the history of robots.⁴⁶ According to Velentza *et al.*, the study found that the Nao robot's cheerful personality and expressive body movement improved students' knowledge acquisition and enjoyment.⁴⁷ In another study conducted by Vitale and Iacono, the Pepper robot was used to deliver a mathematics lesson to high school students.⁴⁸ The results showed that the Pepper robot increased listener engagement and enjoyment by providing immediate, personalized feedback, thereby significantly improving student performance.

The narrated PowerPoint presentation also improved students' carbon literacy learning outcomes. Like the robot storytelling, the PowerPoint presentation also enhanced students' performance. This improvement in students' performance implies that the control group also liked the PowerPoint presentation. 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.

The robot-assisted digital storytelling presentation produced a better learning outcome than the narrated PowerPoint training. Although both robot storytelling and PowerPoint presentations improved their respective groups' performance in the above discussions, as indicated by post-test scores compared with pre-test scores. Here, comparing the two post-tests allows 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 results of the study confirm those of a study by Chen, Hsieh, and Lee.⁴⁹ The study by Chen, Hsieh, and Lee examined the relationships among digital storytelling outcomes, emotions, and grit in robot and PowerPoint presentations.⁵⁰ The result was that the robot enhanced students' grit, positive emotions, and self-perceptions more effectively than the PowerPoint presentation did. 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.

RECOMMENDATIONS

The study's main contribution to addressing the ongoing climate change problem is the use of robot-assisted digital storytelling to enhance students' carbon literacy. Enhancing their understanding of carbon literacy will go a long way to reducing their carbon footprint and minimizing the effects of greenhouse gases.

Therefore, the study recommends that educational authorities consider using robot storytelling to provide carbon literacy education and promote climate awareness in schools. In addition, manufacturers of social robots should produce more robots that can play music and display images, as well as talk, to enable instructors to deliver engaging lessons to learners.

⁴⁶ Anna-Maria Velentza, Nikolaos Fachantidis, and Sofia Pliasa, "Which One? Choosing Favorite Robot After Different Styles of Storytelling and Robots' Conversation," *Frontiers in Robotics and AI* 8 (September 9, 2021), <https://doi.org/10.3389/frobt.2021.700005>.

⁴⁷ Velentza, Fachantidis, and Pliasa, "Which One? Choosing Favorite Robot After Different Styles of Storytelling and Robots' Conversation."

⁴⁸ Antonio Vitale and Umberto Dello Iacono, "Using Social Robots as Inclusive Educational Technology for Mathematics Learning through Storytelling," *European Public & Social Innovation Review* 9 (September 16, 2024): 1–17, <https://doi.org/10.31637/epsir-2024-672>.

⁴⁹ Chen Hsieh and Lee, "Digital Storytelling Outcomes, Emotions, Grit, and Perceptions among EFL Middle School Learners: Robot-Assisted versus PowerPoint-Assisted Presentations."

⁵⁰ Chen Hsieh and Lee, "Digital Storytelling Outcomes, Emotions, Grit, and Perceptions among EFL Middle School Learners: Robot-Assisted versus PowerPoint-Assisted Presentations."

LIMITATIONS

The main limitation of the study is the limited features of the Nao robot used for the lesson delivery. The Nao robot could not play music or display images, so lesson delivery was limited to speech and gestures.

CONCLUSION

This study employed robot-assisted digital storytelling to deliver a lesson on carbon literacy to selected students, aiming to enhance their understanding of the topic. In addition, the study compared the robot storytelling lesson to a similar lesson that uses a narrated PowerPoint presentation. The study used an experimental design method for the activities. The selected students were divided into experimental and control groups. 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 took pre-tests to assess their carbon literacy. A post-test was also conducted at the end of the lesson delivery to determine the carbon literacy knowledge acquired through the training. The study found that both robot-assisted digital storytelling and narrated PowerPoint presentations improved students' understanding of carbon literacy. However, robot-assisted digital storytelling enhanced students' knowledge better than the narrated PowerPoint presentation. The results of this study suggest that robot-assisted digital storytelling is an effective method for learners.

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