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Emotional Responses to Various Digital Puppet Designs in Children's Environmental Storytelling Sessions

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ABSTRACT

This quasi-experimental study explored how different digital puppet character designs affect the emotional experiences of 5- to 6-year-olds during environmental storytelling sessions. The research focused on two emotional dimensions: pleasure and arousal. Thirty kindergarten students participated, interacting with five distinct digital puppet designs over five consecutive days. Each 10-minute session featured a unique story with a consistent environmental theme to maintain engagement. Children's emotional responses were measured using the Self-Assessment Manikin (SAM) questionnaire, which rates pleasure and arousal on a nine-point scale. Data were analyzed using ANOVA tests. Results showed positive mean scores for both pleasure and arousal across all puppet designs. No significant differences were found in emotional responses across designs, except for Wayang Kulit, which elicited significantly higher pleasure levels. These findings suggest that children respond positively to a variety of digital puppet designs when properly tailored to their preferences, highlighting the effectiveness of digital puppetry in environmental storytelling. This study emphasizes the potential of diverse digital puppet characters to engage young learners emotionally in educational content, particularly on environmental issues.

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Children; digital puppetry; emotion; environmental; puppet design; storytelling

Storytelling is a powerful art form that communicates human experience, making a wide range of subjects and complex themes more accessible and relatable (NYU, n.d.). For example, environmental and climate change issues, though widely recognized, can be shared effectively through storytelling, which has the unique ability to frame these topics within culturally meaningful narratives (Harris, 2019; Rice et al., 2015). This strength of storytelling has led to growing calls for climate science communicators to adopt it as a tool for fostering awareness and empathy (Harris, 2019). However, despite these calls, there remains little consensus on what constitutes an effective climate story or the ideal ways to communicate these narratives (Harris, 2019). This study addresses this challenge by exploring storytelling strategies that not only inform but also engage, specifically targeting young audiences in a way that fosters emotional connection and curiosity about environmental issues.

Since this study targets children as its primary audience, it is necessary to move beyond traditional storytelling methods and embrace more contemporary approaches (Rahiem, 2021). Storytelling has evolved with digital technology, introducing new tools and approaches that transform the storytelling landscape. Digital media has become increasingly popular among children, who are often more familiar with digital interactions than with books (Hopkins et al., 2013; Rahiem, 2021). Recognizing this shift, digital puppetry storytelling has emerged as an innovative approach, bridging traditional puppetry and digital interactivity, which aligns well with educational purposes. Such applications also

offer opportunities to bring traditional storytelling methods, like puppetry, into digital formats that resonate with young audiences.

In the design and development of digital puppetry, three core components play an essential role: technical tools for user control and display, principles of character design, and the storytelling framework itself. Given this study's focus on media as a storytelling strategy, the primary emphasis will be on character design principles, specifically the appearance of digital puppets and its effects on children's emotional responses. Thus, the aim of this study is to examine the emotional engagement of children in response to various digital puppet character designs, particularly as a way to enhance educational storytelling on environmental issues.

The theme of climate change was intentionally chosen for its potential to foster early environmental awareness while remaining simple and accessible for young children. Given that the primary focus of this study is on character design and its influence on emotional engagement, it was essential to select a theme that is both meaningful and straightforward. Climate change, as presented in this study, is framed in an age-appropriate manner to avoid complexities that might detract from the study's emphasis on character appearance. By choosing a topic that is easy for children to grasp, we aimed to ensure that the emotional responses observed would be more directly attributable to the visual characteristics of the digital puppets rather than any cognitive challenges posed by the content itself.

Digital puppetry storytelling

Storytelling is a social and cultural activity centered on sharing stories for education, entertainment, cultural preservation, and inspiring moral values, particularly among children. It is widely recognized that storytelling activities can significantly improve children's learning (Cekaitea & Björk-Willén, 2018; Hardiyanti et al., 2022). In modern education, storytelling is employed across various disciplines and educational levels, including higher education (Hava, 2021; Tzima et al., 2020). Skillful storytelling enables listeners to grasp complex concepts and ideas more meaningfully (Omar et al., 2023; Suzuki et al., 2018).

With technological advancements, diverse storytelling approaches using digital media have been extensively explored to enhance engagement, enjoyment, and educational benefits among children (Garzotto et al., 2010; Mohd Yusof et al., 2024). This exploration has led to the emergence of the term "digital storytelling." Digital storytelling involves composing and communicating stories using digital media, including short videos, games, blogs, and social networking sites (Alexandrakis et al., 2020).

The digital storytelling methods identified by Alexandrakis et al. (2020) are primarily asynchronous, not designed for real-time storytelling. These methods offer limited freedom and flexibility for storytellers in communicating their stories. To address these limitations, a more adaptable approach is the utilization of traditional puppetry storytelling methods in a digital format, which is the focus of this research.

Digital puppetry storytelling combines the age-old tradition of puppetry with modern digital technology, creating an interactive and dynamic storytelling medium (Wibawa, 2024). Unlike pre-recorded animated stories, which are fixed and unalterable, digital puppetry allows for immediate interaction and adaptation (Leite, 2024), giving storytellers—often teachers—the flexibility to adjust the narrative based on children's reactions, curiosity, or engagement levels. This real-time responsiveness is invaluable in educational settings, as teachers can pause to explain specific themes, answer questions, or emphasize particular points, ensuring that the story aligns with the children's interests and understanding. This adaptability not only makes the storytelling experience more engaging but also enables a personalized approach, where the narrative evolves organically to meet the needs of the young audience. Digital puppetry thus transforms storytelling from a passive experience into an active, responsive journey, fostering deeper engagement, empathy, and learning among children (Karaolis, 2023).

Digital puppet appearance

Storytelling based pedagogy in children education can be mediated using puppets, as puppets are always popular among children (Halimah et al., 2020). For storytellers, puppets can be an essential and effective tool to keep children's attention and listening (Halimah et al., 2020).

In many countries, puppets are often associated with history and culture. Efforts to preserve this history and culture are being made by expanding the use of puppetry for various purposes with diverse approaches and methods (Halimah et al., 2020; Liang et al., 2023; Zhao, 2020; Zhao et al., 2019). For instance, interactive digital artwork that captures participants' motion with Kinect to control the motion of Chinese shadow puppets demonstrates how technology can revitalize traditional forms (Jiang & Cao, 2021). Adapting this concept, a similar approach can be applied to digitize local traditional storytelling agents, such as Wayang Kulit in Malaysia.

Despite the frequent use of puppets in storytelling, there are few studies on the impact of puppet appearances on the storytelling experience (Kim et al., 2018). This gap raises questions about learners' acceptance and experiences, particularly concerning the character design or appearance of the puppet, especially in a digital context. This issue is critical when digital puppets are used for educational purposes. Studies in educational animation and games clearly demonstrate the impact of character design on students' learning, experience, and acceptance (Kogilathah, 2021; Mohd Khairulnizam, 2021; Mohd Najib, 2015; Muhammad Ihsan, 2021; Vicneas, 2020).

Considering the traditional Wayang Kulit puppetry that will be the focus of this research, the design often portrays eerie or scary characters (Yusof & Khor, 2017). People typically feel uneasy or even disgusted by characters that are highly realistic, horrifying, or abnormal, as highlighted by the "uncanny valley" phenomenon (Mori, 2012; Tinwell, 2015). This feeling of uneasiness is often triggered by ambiguity (McAndrew & Koehnke, 2016). When people see entities that are almost but not quite human, it creates a tension that feels unpleasant (McAndrew & Koehnke, 2016). Such effects are frequently used to heighten horror or scariness in movies, with human-like appearances infused into non-human entities, such as dolls (*Annabelle*) and clowns (*It*), to terrify audiences (Cherry, 2020). This effect is even more pronounced in children (Tinwell & Sloan, 2014). This unpleasant and frightening effect is inappropriate for educational purposes, particularly among children.

Therefore, the reconstruction of traditional shadow puppetry, as highlighted by Jiang and Cao (2021), should not be limited to digital control and display but also should include a redesign of the characters' appearances. This is crucial if the digitalization of traditional methods is intended to not only preserve heritage but also serve educational purposes, particularly for children. This research will address this issue by introducing contemporary digital Wayang Kulit for educational purposes. However, it will also test other puppet appearances to identify designs that are most engaging and effective for children's learning.

Puppet design and children's emotions

Children's emotions play a crucial role in their learning process, as emotions can significantly influence motivation, attention, and learning experiences (Abdul et al., 2019). Therefore, educators need to foster a joyful and enthusiastic atmosphere around the topics being taught to enhance children's interest in learning. Negative emotions, such as anxiety, worry, or fear, can disrupt the learning process (Wan Talib & Amran, 2023). Consequently, children experiencing negative emotions often face difficulties in concentrating, understanding, and retaining the information presented by teachers (Yee & Yunus, 2021).

Educators play a vital role in managing children's emotions during the learning process. Creating a positive environment is essential to facilitate enjoyable and empathic interactions (Mohammad & Mohamed, 2020). Understanding children's feelings can help mitigate negative emotions and enable them to focus better on learning (Rathod et al., 2022). Teaching techniques that incorporate emotional aspects, such as activities involving play, art, and music, can stimulate positive emotions and enhance

children's creativity (Wahyuni & Safitri, 2021). Additionally, personalized approaches to fostering individual interests can strengthen the teacher-student relationship (Greenhow & Galvin, 2020). Effective communication, empathic listening, and providing support are crucial for understanding children's emotional responses (Ding et al., 2020).

In conclusion, understanding the emotional structure of children is essential in the learning process. Effective emotional management can facilitate better learning outcomes (Drigas & Papoutsis, 2020; Pal Thamburaj et al., 2024). Educators bear a significant responsibility to create an environment that caters to children's emotional states, thereby fostering their potential and achieving success in learning (Yunisari & Yusra, 2020).

Thus, the emotional responses of children are particularly important when introducing new educational tools, such as digital puppetry. The design and appearance of digital puppets can significantly impact children's emotions during storytelling sessions. By creating digital puppets with appealing and emotionally engaging designs, educators can enhance children's learning experiences. Positive emotional engagement through well-designed digital puppets can mitigate negative emotions and improve attention, understanding, and retention of the educational content. This study aims to explore how different digital puppet designs influence children's emotions in environmental storytelling sessions, providing insights for educators to effectively integrate digital puppetry in their teaching strategies.

Environmental storytelling

Early environmental education plays a crucial role in fostering curiosity and passion about nature and climate change issues among children (Ichsan et al., 2022; Kinnear, 2021). By introducing these concepts at a young age, children can develop lasting habits that contribute to environmental sustainability, such as recycling, using reusable bags for shopping, turning off water while brushing their teeth, keeping lights off when not in use, and using reusable water bottles (Kinnear, 2021). Instilling these habits early on can lead to lifelong environmental responsibility.

One effective way to instill these habits and attitudes in children is through storytelling methods (Haq, 2018). Storytelling has the power to generate empathy and understanding, making complex issues like climate change more relatable and inspiring listeners to take positive actions (Bloomfield & Manktelow, 2021). When children hear compelling stories about the impact of climate change and the importance of protecting the environment, they are more likely to internalize these messages and incorporate environmentally friendly practices into their daily lives.

Given the potential of storytelling to effectively communicate and instill environmental values, it is important to explore and identify the most effective alternative storytelling methods. This includes examining different formats and mediums, such as digital puppetry, to determine which approaches resonate most with children. By finding the most effective storytelling techniques, educators can enhance early environmental education, ensuring that the next generation is well-equipped to address and mitigate the challenges of climate change.

Methodology

This quantitative study employs a quasi-experimental method to investigate the emotional effects of different digital puppet appearances on 5- and 6-year-olds. The research seeks to understand how visual characteristics of digital puppets influence young children's emotional responses, specifically in terms of pleasure and arousal, during environmental storytelling sessions. These two dimensions—pleasure and arousal—are key components of emotional response, as they play a critical role in shaping children's engagement and learning experiences (Kao & Mou, 2023).

Research questions

Based on the literature review, two research questions were formulated as follows:

- Is there a significant difference in children's pleasure due to the various digital puppet character designs?
- Is there a significant difference in children's arousal due to the various digital puppet character designs?

Digital puppetry design

The overall design and development of the digital puppets were meticulously crafted following established multimedia design principles. This approach ensures that the digital puppets are not only visually appealing but also educationally effective and engaging for children. The digital puppet design was validated by three experts, specializing in early childhood education, animation, and instructional design.

Each expert brings a wealth of practical experience, with a range of over 10 years of professional expertise in their respective fields. Furthermore, the experts hold qualifications of at least a bachelor's degree and a master's degree, providing a solid foundation in their areas of specialization. Additionally, the instructional design expert holds a PhD and has extensive research experience, bringing a high level of academic insight to the validation process.

Feedback from these experts was obtained through a structured formative and summative evaluation process. During the formative phase, each expert viewed both the digital puppet and the display session, assessing how effectively the design aligned with educational goals and how it resonated emotionally with young learners. This initial phase allowed for the identification of areas needing improvement early in the development process. Feedback was provided verbally in an informal setting, creating an open and collaborative environment that facilitated clear communication of expert insights and suggestions.

Following the formative feedback, adjustments were made to the digital puppets to enhance their developmental appropriateness, visual appeal, and engagement potential. During the summative phase, experts reviewed the refined puppets to confirm the improvements, further ensuring that the design met the highest standards of educational content delivery and emotional engagement. This collaborative, iterative process helped to create digital puppets that provide an enriching and impactful learning experience for young children.

Children themselves were also involved in the testing and validation process. This direct feedback from the end-users—children age 5 and 6—provided invaluable insights into how they interact with the digital puppets. Observations and feedback from the children helped to fine-tune the design to better cater to their preferences, ensuring that the puppets are both captivating and enjoyable.

To bring the digital puppetry storytelling sessions to life, the Leap Motion Controller was selected for the real-time control of the animation (Figure 1). This cutting-edge technology allows for precise and intuitive manipulation of digital puppets, enabling the storyteller to control the characters' movements with hand gestures (Li & Cao, 2021). The use of Leap Motion ensures a seamless and interactive storytelling experience, closely mimicking the dynamic nature of traditional puppetry.

In an effort to preserve the cultural essence of traditional Wayang Kulit, the presentation method for the digital puppets closely resembles that of traditional performances. In Wayang Kulit, puppets are typically controlled behind a screen with a light source casting shadows that depict the story. Adapting this technique to a modern context, an LCD projector was utilized to present the digital puppets. The projector casts the animated figures onto a screen, creating a visual effect similar to the shadow puppets of Wayang Kulit.

In this setup, the teacher assumes the role of the environmental storytelling agent. By taking on this role, the teacher not only narrates the story but also interacts with the digital puppets in real-time, creating a dynamic and engaging educational experience. The teacher's ability to control the puppets' movements using Leap Motion allows for a highly interactive storytelling session, where the characters can respond to the narrative and the children's reactions.

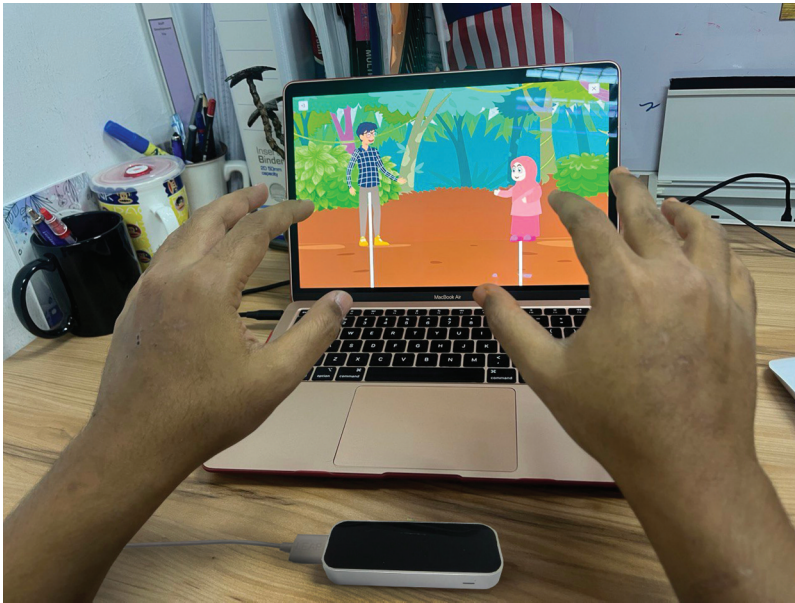


Figure 1. Digital puppetry software and leap motion controller.

Character selection and design

In the development of digital puppets for children's environmental storytelling sessions, five distinct character designs were produced. The selection of these characters was strategically based on the outcomes depicted in the uncanny valley graph by Masahiro Mori (Figure 2). This graph illustrates how different levels of realism in character design can affect human emotional responses, with a particular focus on avoiding the uncanny valley, where characters

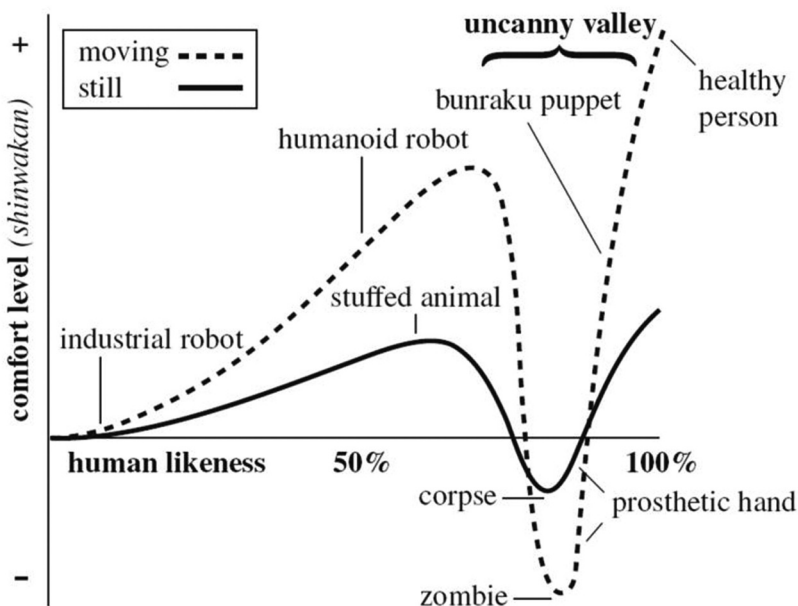


Figure 2. Masahiro Mori's uncanny valley graph (source: MacDorman et al., 2009).

evoke feelings of eeriness or discomfort. The characters selected for this study aimed to elicit positive emotional responses, ensuring that the puppets are engaging and not unsettling for children.

Actual human character

The first character design represents an actual human—native look (Figure 3). This character was designed to be highly realistic, closely resembling real human appearance and movements. The familiarity and native appearance of this character aim to evoke positive emotional responses and a sense of relatability and trust from the children. This design choice leverages the natural affinity children have toward human figures, making it an effective tool for educational storytelling.

Two-dimensional character resembling an actual human

The second character is a two-dimensional model that closely resembles an actual human but with slight stylizations to avoid crossing into the uncanny valley (Figure 4). This character balances realism with a touch of animation, providing an engaging and approachable appearance. By maintaining a high level of realism without reaching the point of eeriness, this design aims to capture children's attention and elicit positive emotions, enhancing their learning experience.

Humanoid robot character

The third character design is a humanoid robot (Figure 5). This character was chosen for its ability to evoke curiosity and interest while avoiding the negative emotional responses associated with the uncanny valley. The humanoid robot combines familiar human-like features with a distinctly robotic appearance, making it intriguing yet comfortable for children. This design aims to foster a sense of wonder and engagement, making the storytelling sessions more captivating.



Figure 3. Actual human character.



Figure 4. Two-dimensional character resembling an actual human.

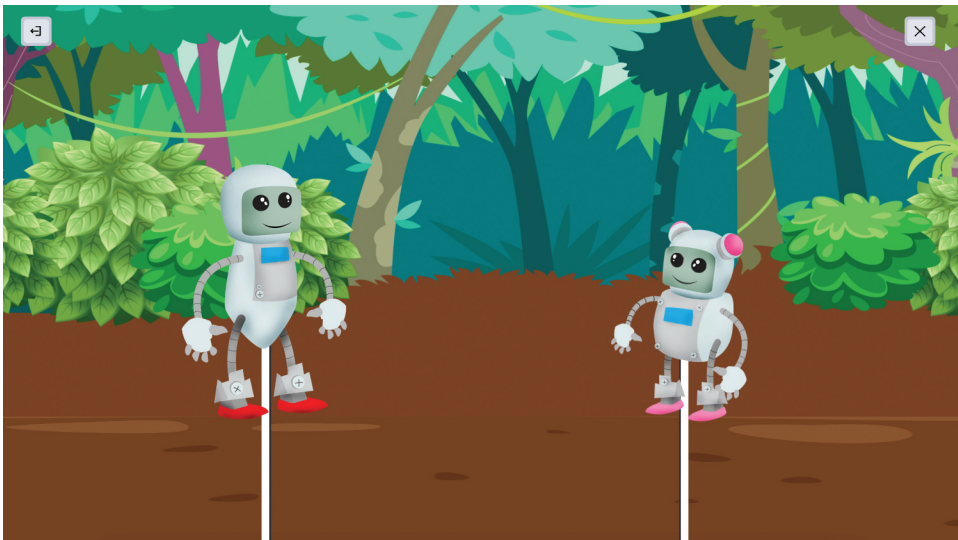


Figure 5. Humanoid robot character.

Animal character

The fourth character is an animal figure, designed to be cute and appealing to young children —Tiger, the national symbol (Figure 6). Animals are often beloved by children and can evoke strong positive emotional responses. This character was designed with friendly and exaggerated features to maximize appeal and engagement. By incorporating an animal character, the storytelling sessions can tap into children’s natural affinity for animals, making the educational content more relatable and enjoyable.



Figure 6. Animal character.

Wayang Kulit character

The fifth character design is based on traditional Wayang Kulit puppetry, which might typically fall into the uncanny valley due to its stylized and sometimes eerie appearance. However, this character was carefully designed to retain the cultural essence of Wayang Kulit while ensuring it is not unsettling for children (Figure 7). This involved softening some of the more intense features and adding elements that are more familiar and comforting. By modernizing the Wayang Kulit design, this character aims to introduce children to cultural heritage in a way that is engaging and emotionally positive.

By incorporating a diverse range of character designs, this study aims to understand how different visual characteristics influence children's emotional responses during environmental storytelling



Figure 7. Wayang Kulit character.

sessions. The goal is to identify which puppet appearances are most effective in creating a positive and engaging educational experience.

Procedure

This study used a quasi-experimental method to examine the effects of different digital puppet character designs on children's emotional experiences during environmental storytelling sessions, focusing on pleasure and arousal. A one-group posttest-only design was applied, where all participants were exposed to the experimental conditions and their emotional responses were measured after intervention (Keith, 1990; Krishnan, 2019). This approach was suitable for evaluating emotional engagement in a controlled educational setting, where full randomization is often impractical. Since the study aimed to capture immediate emotional effects, no pre-test was conducted, as emotional engagement is context-dependent and best assessed directly following the intervention.

The research was conducted with 30 kindergarten students age 5 and 6 years old, all of whom were treated as part of the experimental group. This design ensured that each child's emotional responses were directly attributable to the specific puppet design they experienced, without being influenced by preconceived emotional states or other variables. By using this approach, the study effectively captured the impact of visual character design on emotional engagement, providing meaningful insights into how digital puppets can be optimized for educational storytelling.

The same group of children participated in all the environmental storytelling sessions, each featuring a different digital puppet design. The study was conducted over five different days, with one design and story presented each day by the same teacher. Although the stories varied, they all shared a consistent environmental theme to maintain conceptual coherence. The stories were intentionally kept simple to avoid cognitive burden, with topics related to recycling, the impact of smoking, safe water consumption, not littering, and river pollution. Each storytelling session lasted approximately 10 minutes to ensure that boredom did not influence the study's findings.

Immediately after each storytelling session, the children were asked to provide their emotional responses using the Self-Assessment Manikin (SAM) questionnaire. The SAM questionnaires were distributed, and the children were given approximately 20 seconds to complete them. This duration was considered suitable based on Bradley and Lang's (1994) study.

The data obtained from the SAM questionnaires were analyzed quantitatively using an ANOVA statistical test to determine if there were significant differences in the pleasure and arousal levels elicited by the different character designs of the digital puppets. This structured approach aimed to isolate the effects of the avatar designs on children's emotional experiences during environmental storytelling, providing valuable insights into how different digital puppet designs influence emotional responses in children.

In accordance with ethical considerations, consent was obtained from caregivers for all child participants prior to their involvement in the study. Caregivers were fully informed about the study's purpose, procedures, potential risks, and benefits. Participation was entirely voluntary, and caregivers were assured that they could withdraw their child from the study at any time without any negative consequences. The study was conducted in full compliance with the ethical guidelines and regulations of Universiti Pendidikan Sultan Idris, ensuring the safety, privacy, and well-being of all child participants.

To enhance the reliability of the findings and address potential threats to validity, which are critical in a quasi-experimental design, several measures were implemented. All participating children were confirmed to have no prior experience with digital storytelling or puppetry, ensuring their responses were purely influenced by the experimental conditions. Additionally, none of the children had any previous exposure to the culturally specific Wayang Kulit puppetry, eliminating the possibility of familiarity or preconceived notions affecting their emotional responses. To maintain consistency, no

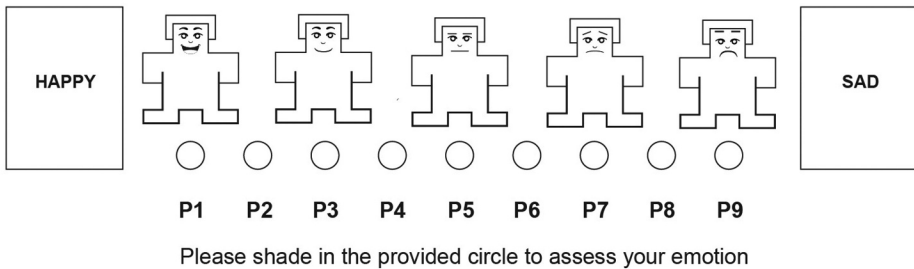
special effects or additional sound effects were included, and the background scenery was kept uniform across all designs, aligned with the environmental theme of the stories. Based on expert feedback, the use of a plain black background was avoided, as it was deemed unsuitable for children storytelling. The storytelling sessions were conducted in a familiar setting—the children’s kindergarten—by their regular teacher in their ordinary classroom of approximately 30 students, further ensuring a natural and comfortable environment for the participants.

Test instrument

The Self-Assessment Manikin (SAM) was used to gather children’s emotional feedback. This test features a pictorial mood-reporting questionnaire, where students evaluated their emotional experiences based on a 9-point pictorial mood scale assessing pleasure and arousal (Figure 8). The choice of this scale was based on the SAM scoring system developed by Bradley and Lang (1994, 1999). For pleasure, the emotional state ranged from a happy, smiling manikin (1, indicating the most positive emotion) to an unhappy, frowning manikin (9, indicating the most negative emotion), with 5

ID:
 CHARACTER CODE:

Pleasure Emotion Scale



ID:
 CHARACTER CODE:

Arousal Emotion Scale

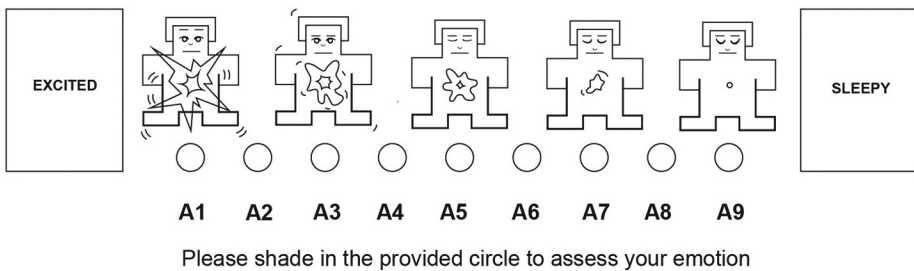


Figure 8. Pictorial mood reporting scale of SAM.

representing a neutral emotional state. Similarly, for arousal, the scale ranged from a highly energetic manikin (1, representing the highest level of arousal) to a relaxed manikin with closed eyes (9, representing the lowest level of arousal), with 5 again considered neutral (Tsonos & Kouroupetroglou, 2008).

In this study, only the pleasure and arousal dimensions of the SAM were applied to measure children's emotional responses. According to Mehrabian and Russell's work, pleasure is defined as the feeling of happiness or satisfaction, and arousal refers to the level of stimulus or excitement (Bakker et al., 2014; Russell & Mehrabian, 1977). These definitions are foundational to their pleasure-arousal-dominance (PAD) model, which has been widely used to describe and measure emotional states.

Given that pleasure and arousal are directly related to emotional and cognitive responses—pleasure reflecting happiness and satisfaction (affective) and arousal indicating the level of stimulus or excitement (cognitive)—this study will focus on these two dimensions (Bakker et al., 2014). Dominance, categorized as a conative concept, pertains more to control and action, which is less relevant to the study's goal of understanding emotional responses during environmental storytelling (Bakker et al., 2014). Thus, emphasizing pleasure and arousal aligns better with assessing the immediate emotional impact of digital puppetry on young children.

One of the main strengths of the SAM model is its visual orientation, which uses characters to depict each emotion. This allows respondents, especially children, to quickly assess their emotions in less than 20 seconds using the SAM scale. The SAM model is also suitable for use with both children and adults. The use of graphic characters helps respondents easily understand the dimensions and scales of emotions. This visual approach makes the SAM model more accessible across different age categories (Khozaei et al., 2020). In summary, the SAM model is very useful and can be readily applied to effectively measure emotional responses in children, particularly due to their inability to read and comprehend text-based questionnaires.

Given the developmental nature of young children, the procedures for using the SAM scale were explained to them by their teacher before the session. The teacher guided the children to understand the scale and ensured they were familiar with how to respond. The 20-second time limit for responses was applied to capture their immediate emotional reactions, which aligns with Bradley and Lang's (1994) study, where such a duration was considered suitable for assessing emotional responses without cognitive overloading. This time frame ensures spontaneous, instinctive responses that are more reflective of their immediate emotional state. The SAM scale has been previously used effectively with children, particularly because of its visual and simple design, which allows even very young participants to provide feedback quickly and accurately (Greenbaum et al., 1990; Monnier et al., 2016; Van Gorp & Verheyen, 2024; von Leupoldt et al., 2007).

Data analysis and findings

A one-way ANOVA analysis was conducted to test for any significant differences in dependent variable among a group of children while viewing the different digital puppet designs during environmental storytelling sessions. Prior to the ANOVA analysis, all necessary assumptions, such as normality and equality of variance, were thoroughly verified to ensure the validity of the research data. This rigorous approach was essential to accurately address the research questions.

Research question 1

Is there a significant difference in children's pleasure due to the various digital puppet character designs?

The results of this analysis (Table 1) indicate a significant difference in pleasure mean values among the different digital puppet design storytelling session; $F(4,145) = 4.29, p < 0.05$, partial eta squared = 0.11, which denotes a moderate effect size according to Cohen's 1998 guidelines (Pallant, 2010). The overall post hoc Tukey test showed no significant differences between most pairs of digital puppet character designs.

Table 1. Summary of one-way ANOVA analysis for first research question.

Source	Type III sum of squares	Df	Mean square	F	Sig.	Partial eta squared
Corrected Model	110.97 ^a	4	27.74	4.29	.00	0.11
Intercept	1221.23	1	1221.23	188.82	.00	0.57
DESIGN	110.97	4	27.74	4.29	.00	0.11
Error	937.80	145	6.47			

^aR Squared = .106 (Adjusted R Squared = .081).

However, significant differences were found for the pairs Humanoid Robot and Wayang Kulit (MD = 2.40, $P < 0.05$), Two-Dimensional Human and Wayang Kulit (MD = 1.83, $P < 0.05$), and Actual Human and Wayang Kulit (MD = 2.27, $P < 0.05$). The overall differences indicated that the Humanoid Robot, Two-Dimensional Human, Actual Human, and Animal obtained lower mean scores compared to Wayang Kulit. In conclusion, it can be summarized that the Humanoid Robot, Animal, Two-Dimensional Human, and Actual Human are comparable and fall within the significantly positive pleasure emotion level. In contrast, Wayang Kulit is significantly different from the other character designs and falls at a pleasure emotion level approaching neutral.

Based on the mean scores (Table 2), none of the designs fell within the negative pleasure emotion zone. Whereby, every digital puppet design fell into a positive or neutral pleasure zone.

Research question 2

Is there a significant difference in children’s arousal due to the various digital puppet character designs?

The results of this analysis (Table 3) indicate no significant difference in arousal mean values among the different digital puppet design storytelling session; $F(4,145) = 0.23, p > 0.05$, partial eta squared = 0.01, which denotes a small effect size according to Cohen’s 1998 guidelines (Pallant, 2010). Based on the mean scores (Table 4), none of the designs fell within the negative arousal emotion zone. Whereby, every digital puppet design fell into a positive arousal zone.

Table 2. Digital puppet design level positioning in terms of pleasure mean score.

Puppet Design	Mean score	Standard Deviation	N
Humanoid Robot	2.07	2.33	30
Actual Human	2.20	2.33	30
2D Human	2.63	2.86	30
Animal	2.90	2.07	30
Wayang Kulit	4.47	3.00	30

Table 3. Summary of one-way ANOVA analysis for second research question.

Source	Type III sum of squares	Df	Mean square	F	Sig.	Partial eta squared
Corrected Model	7.29 ^a	4	1.82	0.23	0.92	0.01
Intercept	1466.41	1	1466.41	184.05	0.00	0.60
DESIGN	7.29	4	1.82	0.23	0.92	0.01
Error	1155.30	145	7.97			

^aR Squared = .006 (Adjusted R Squared = -.021).

Table 4. Digital puppet design level positioning in terms of arousal mean score.

Puppet Design	Mean score	Standard deviation	N
2D Human	2.80	2.63	30
Humanoid robot	3.10	3.11	30
Animal	3.23	2.56	30
Wayang kulit	3.03	2.70	30
Actual human	3.47	3.07	30

In summary, the findings indicate significant differences in pleasure levels among the various digital puppet designs. While the Humanoid Robot, Two-Dimensional Human, Actual Human, and Animal designs all fell within the positive pleasure emotion range, the Wayang Kulit design scored toward the neutral pleasure zone, showing comparatively lower emotional satisfaction. Despite this, none of the designs fell within the negative pleasure emotion range. Regarding arousal, no significant differences were observed among the designs, with all digital puppets consistently eliciting positive arousal levels. None of the designs fell into the negative arousal range, demonstrating that all designs effectively engaged the children.

In addition, informal observations over the five days of storytelling sessions indicated that the children consistently appeared happy and excited. Their enthusiasm and engagement were evident throughout each session, suggesting a generally positive reception to the environmental storytelling experience, regardless of the digital puppet design. However, as this study primarily employed a quantitative approach, the qualitative aspects of the children's experiences were not explored in detail. To further enhance these findings and provide a more comprehensive understanding of the children's emotional engagement, future research should incorporate qualitative methods to capture deeper insights into their perceptions and experiences during the storytelling sessions.

Discussion

Storytelling plays a vital role in cultivating environmental awareness among children, as it captures their attention, engages their emotions, and fosters curiosity about important issues like sustainability and conservation. To achieve this, the emotional dimensions of pleasure and arousal are key. Pleasure reflects the level of happiness or satisfaction children experience, while arousal indicates their level of excitement or alertness. Together, these emotional responses create a foundation for meaningful engagement, helping children connect with the story and retain its messages more effectively.

This study aimed to investigate how different digital puppet character designs influence children's emotional responses, specifically focusing on pleasure and arousal during environmental storytelling sessions. Effective digital puppetry relies on the seamless integration of three core components: technical tools for user control and display, principles of character design, and the storytelling framework. These components are interrelated, working together to deliver an engaging and impactful storytelling experience. By addressing the character design component in particular, this study optimized the visual elements of the puppets to enhance their emotional and educational impact. The findings provide valuable insights into how thoughtful character design can enhance children's emotional engagement and potentially contribute to the effectiveness of environmental storytelling in fostering awareness and learning.

Research question 1

The analysis results indicate a significant difference in pleasure mean values among the different digital puppet design storytelling sessions. However, the overall post hoc Tukey test revealed no significant differences between most pairs of digital puppet character designs, except for the pairs Humanoid Robot and Wayang Kulit, Two-Dimensional Human and Wayang Kulit, and Actual Human and Wayang Kulit. The overall differences showed that the Humanoid Robot, Two-Dimensional Human, Actual Human, and Animal designs obtained lower mean scores compared to Wayang Kulit. Moreover, the Humanoid Robot, Animal, Two-Dimensional Human, and Actual Human designs were comparable and consistently elicited significantly positive pleasure emotions. In contrast, the Wayang Kulit design was significantly different from the other character designs, falling at a pleasure emotion level approaching neutral. Despite this, all digital puppet designs resulted in either positive or neutral pleasure emotions, with none falling within the negative pleasure emotion zone.

A critical analysis of these findings can be informed by Mori's uncanny valley theory, which suggests that characters that are almost but not quite human-like can evoke feelings of eeriness or discomfort (Mori, 2012; Tinwell, 2015). The traditional Wayang Kulit puppets, with their exaggerated and sometimes eerie characteristics, may fall into this uncanny valley, leading to lower pleasure ratings among children. This aligns with prior studies indicating that designs evoking discomfort or ambiguity are less likely to generate positive emotional responses (McAndrew & Koehnke, 2016; Tinwell & Sloan, 2014). The more child-friendly designs of the Humanoid Robot, Animal, Two-Dimensional Human, and Actual Human avoided these pitfalls, likely contributing to their higher acceptance.

Despite the careful redesign of Wayang Kulit puppets to retain their cultural essence while ensuring they were not unsettling for children, the design was still not as well accepted as the other designs. This redesign involved softening some of the more intense features and adding elements that were more familiar and comforting. By modernizing the Wayang Kulit design, the intention was to make it more appealing to children. However, it still did not achieve the same level of positive emotional response as the other designs. Nonetheless, it did not fall into the negative pleasure mood, possibly due to the new design approach mentioned, which mitigated some of the more unsettling aspects.

The importance of visual and emotional engagement in learning, particularly for young children, is well-documented (Cekaitea & Björk-Willén, 2018; Suzuki et al., 2018). This study underscores the necessity of designing digital puppets that are both culturally significant and emotionally engaging. The positive reception of the Humanoid Robot, Animal, Two-Dimensional Human, and Actual Human designs suggests that children respond more favorably to characters that are visually appealing and less likely to evoke discomfort. These findings highlight the potential of digital puppetry as an effective tool for environmental education, leveraging engaging designs to convey complex concepts (Garzotto et al., 2010; Hava, 2021).

The findings suggest that digital puppets with more familiar and appealing characteristics, such as the Humanoid Robot, Animal, Two-Dimensional Human, and Actual Human designs, are better received by children because they avoid the uncanny valley effect. These designs likely foster a sense of relatability and comfort, enhancing children's emotional engagement and making the environmental storytelling session more effective. On the other hand, the Wayang Kulit design's traditional and stylized features, while culturally significant, may appear unsettling to children in a digital format, resulting in lower pleasure scores.

This study highlights the importance of balancing cultural authenticity with visual appeal in designing digital puppetry for environmental storytelling. The results emphasize that with careful design considerations, digital puppetry can be a powerful medium for engaging children in environmental storytelling. Future research should explore developing a more child-friendly design of Wayang Kulit that maintains its cultural essence while enhancing its appeal to young audiences. This could involve adjusting the character's visual elements to be less exaggerated and more relatable, ensuring that the design resonates positively with children and effectively supports their learning experience.

Research question 2

The results of the analysis indicate no significant differences in the mean arousal values across the different digital puppet design environmental storytelling sessions, with all designs eliciting positive levels of arousal in children.

While the arousal levels were consistently positive across different digital puppet designs, a significant difference was observed in the pleasure ratings, particularly for the Wayang Kulit design, which fell into the neutral pleasure zone. This discrepancy between arousal and pleasure ratings warrants a closer examination of the factors contributing to these emotional responses. The pleasure dimension, which indicates the degree of positive emotional response or enjoyment, was notably lower for the Wayang Kulit design compared to other digital puppets. This design, despite its cultural significance, might have elicited a neutral pleasure response due to its traditional and potentially

unsettling characteristics. These features, which include exaggerated and stylized elements, may not resonate well with young children in a digital format.

In contrast, the arousal ratings for Wayang Kulit were positive and similar to those of other designs. This indicates that, despite the neutral pleasure response, the Wayang Kulit design was able to engage the children and maintain their attention at a level comparable to other puppet designs. This positive arousal response could be attributed to the novelty and cultural richness of the Wayang Kulit design, which may have intrigued the children and kept them alert and engaged during the storytelling sessions.

The findings highlight the complexity of emotional responses to different digital puppet designs. The Wayang Kulit design's ability to elicit positive arousal but neutral pleasure suggests that while the design was engaging, it did not evoke the same level of enjoyment as the other more child-friendly designs. This underscores the importance of balancing cultural authenticity with visual appeal to ensure that digital puppets are both engaging and enjoyable for children. The consistently positive arousal levels across all designs suggest that digital puppetry, regardless of the specific character design, can effectively capture children's attention and maintain their engagement. This consistency in arousal indicates that digital puppetry is a robust method for delivering environmental storytelling, as it can sustain children's interest and alertness throughout the storytelling session.

Conclusion

Storytelling is essential for fostering environmental awareness in children, engaging their emotions and sparking curiosity about sustainability and conservation. Central to this engagement are the emotional dimensions of pleasure and arousal, which help children connect with the story. This study investigated how different digital puppet character designs influence children's emotional responses, focusing on pleasure and arousal during environmental storytelling sessions. Effective digital puppetry depends on the seamless integration of three essential elements: user control tools, character design principles, and the storytelling framework. By optimizing character design, this study demonstrated how thoughtful design choices can significantly enhance emotional engagement in environmental storytelling.

The design of digital puppet characters plays a pivotal role in fostering positive emotional responses during environmental storytelling sessions, especially when the designs are tailored to be child friendly. This study demonstrates that character designs, whether humanoid, animal, or human-like, can elicit positive pleasure and arousal levels in children, as long as they adhere to principles that support young children's cognitive and emotional needs. When the designs are simple, visually engaging, and easy to understand, they tend to evoke positive emotions such as happiness and excitement. This study shows that character designs like Humanoid Robot, Animal, Two-Dimensional Human, and Actual Human effectively promoted pleasure and arousal, highlighting that visually appealing, uncomplicated characters are more likely to capture and maintain children's attention. On the other hand, the Wayang Kulit design, despite efforts to soften its traditionally intense features, received neutral pleasure ratings, indicating that more complex or culturally unfamiliar designs might not be as engaging for young audiences. This finding emphasizes the importance of aligning character design with age-appropriate, child-friendly principles to enhance emotional engagement.

The simplicity of the environmental story itself also played a crucial role in fostering positive emotional responses. As observed in this study, when the story content is not cognitively demanding, children are better able to engage emotionally with the digital puppetry and connect with the characters. In this case, the relatively straightforward environmental theme allowed children to focus more on the emotional experiences generated by the characters. Positive pleasure and arousal levels were achieved across all digital puppet designs, with children responding enthusiastically to the storytelling session. However, this raises an important question: Would the same results be achieved if the storytelling content were more complex or cognitively challenging? While this study focused on

a simple narrative, future research should explore how varying levels of story complexity interact with character design to impact children's emotional responses and engagement. This would help identify the ideal balance between content and design for fostering maximum emotional and educational benefits.

The findings of this study offer valuable insights for instructional designers, teachers, and children. For instructional designers, the results highlight the importance of creating visually appealing and child-friendly digital puppets that elicit positive emotional responses. Combining thoughtful character design with simple, cognitively accessible narratives can enhance children's engagement, interaction, and understanding of key educational themes like environmental awareness. For teachers, the findings provide guidance on selecting or creating digital puppet-based storytelling sessions that align with children's emotional needs, ensuring the characters foster positive emotions and enhance attention and engagement. For children, well-designed digital puppets make environmental storytelling more enjoyable and impactful by fostering emotional engagement, helping them connect with the content and supporting their learning experience.

Limitations

Despite the valuable insights provided by this study, several limitations must be acknowledged. The specific character designs selected for this study were restricted to five designs referenced from the uncanny valley graph, focusing only on characters that fall within the positive emotion zone. This narrow selection may not capture the full spectrum of potential character designs and their impacts. Additionally, while efforts were made to modernize the traditional Wayang Kulit design to be more child-friendly, the study did not explore a wider range of potential modifications that could further enhance its appeal.

Furthermore, the study's focus on emotional responses was limited to pleasure and arousal as measured by the SAM model. This approach does not encompass the full range of possible emotional responses and may overlook other important emotional dimensions. Additionally, the findings are limited to environmental storytelling sessions, which may not fully represent other educational contexts or storytelling themes. The study focused solely on emotional responses and did not assess the impact on children's understanding of environmental issues, which represents a significant area for future research.

Future research should consider a broader range of design modifications, incorporate interactive elements, and explore different storytelling contexts to better understand how these factors influence children's emotional and educational experiences. Longitudinal studies could provide insights into the long-term impact of digital puppetry on children's learning and emotional development. Moreover, future studies should also examine how digital puppetry affects children's comprehension and retention of environmental issues, expanding beyond emotional responses to include cognitive and educational outcomes.

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Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee. Specifically, this study was approved by the Human Research Ethics Committee, Universiti Pendidikan Sultan Idris, approval number 2023-173-01 dated 27 September 2023.

Informed consent

Informed consent was obtained from the institution involved, and all individuals included in the study participated voluntarily.

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