

Impact of Static and Animated eBook Illustrations on Children's Engagement, Enjoyment, and Information Recall

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(a) Static illustration



(b) Basic animated illustration



(c) Focused animated illustration

Figure 1: Examples of three illustration types used in the study: a) Static (conventional) illustration without animations, akin to the initial frame of an animation. b) Basic animated illustration featuring animated elements of significance, such as the cacti (more evident than in the static figure). c) Focused animated illustration emphasizing specific characters, objects, incidents, or continuous change over time through added motion, transitions, or zoom-in effects, as seen with the zooming in on the hieroglyphs.

ABSTRACT

In an exploratory study, we investigated the effects of different types of illustrations on eBook reading engagement among children aged 11 to 12 years. We explored three distinct illustration styles: static (depicting significant events within the story), basic animated (animating story events), and focused animated (emphasizing specific elements or illustrating continuous change over time). Our findings suggest that animated illustrations, especially focused animated illustrations, enhance children's engagement, increase their confidence, and improve recall. Subjective feedback highlighted a strong preference for and greater enjoyment of stories featuring animated illustrations. The majority of children believed that animated illustrations would substantially improve their eBook reading experience.

CCS CONCEPTS

- Human-centered computing → Touch screens; Empirical studies in HCI; E-book readers;
- Social and professional topics → Children;
- Applied computing → Interactive learning environments.

KEYWORDS

Children, e-book, digital book, e-learning, eReader, tablet, middle school, education, classroom, learning, recall

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1 INTRODUCTION

Book illustration is a form of fine art that not only explains the text through compositional construction but also conveys many details about the characters, surroundings, times, and places of action that text alone cannot [64]. The literature consistently demonstrates that

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carefully crafted, meaningful illustrations can enhance children's comprehension and enjoyment of stories [7, 15, 25, 32, 35, 43, 55, 84]. Electronic books, commonly referred to as eBooks, has become one of the dominant mediums for reading, especially to the younger generation [28, 65]. Today, children of all ages have access to eBooks via dedicated eReaders or eReader applications on tablets or smartphones at home, libraries, and even in schools [12, 36, 65, 68, 76, 79]. The soft interfaces of eReaders provide designers with a unique opportunity to make book illustrations interactive and animated, extending the scope of illustrations to showing how an incident took place in the story. In fact, researchers encouraged designing and investigating the effects of animated illustrations, speculating that it could further enhance children's enjoyment, interest, and reading comprehension [14, 83, 89]. However, neither static nor animated illustrations are common in eBooks¹. In this exploratory work, we investigate the effects of static and two different types of animated illustrations on children's engagement and enjoyment with eBooks, their recall of information from the books, as well as their preference for the illustrations. To the best of our knowledge, this is the first study to investigate these effects. Our purpose is to provide recommendations for designing illustrations for eBooks, and encourage further investigations in the area.

2 RELATED WORK

This section reviews relevant literature on illustrations in children's eBooks and design guidelines specific to this context. We exclude studies involving adult users, desktop or legacy tablet computers (refer to Dillon [21] for a review of these works), as well as works on digital libraries [39], children-friendly search interfaces [22, 44], multi-lingual support [1], and graphical feedback in children's applications [3, 4, 57], as they are beyond the scope of this work.

2.1 eBook Reading Experience

Consistent reports indicate that children of all ages are more receptive to reading eBooks than adults [11, 54, 60, 80]. Nevertheless, the impact of eBooks on the reading experience and performance remains a topic of debate. Sunarti et al. [80] conducted a qualitative study that revealed second-grade students finding eReaders easy to use and expressing greater enthusiasm for reading eBooks compared to traditional books. However, the study lacks detailed information about the sample and study procedures, such as the children's prior experience with eReaders or the types of devices used. In a recent study, Shafaati [76] found out that middle and high school students are generally satisfied with reading eBooks, but they tend to grow tired as reading eBooks is error prone and requires more concentration than traditional books. Colombo and Landoni [11] reported that eBooks supporting audio, video, and read-aloud narration features improve preteen's reading experience. It is, however, debatable whether listening to a book constitutes "reading". In contrast, Hancock et al. [30] found out that young adults do not perceive eBooks to be as useful or as easy to use as traditional books.

¹In an informal survey, we examined 150 most downloaded children's eBooks on three popular cross-platform eBook apps (Amazon Kindle, Barnes & Noble Nook, and Google Play Books [30, 65]) that support animations. Among the surveyed eBooks, 70% had no illustrations, while 30% contained static illustrations. None of the eBooks featured animated illustrations.

Yuill and Martin [90] studied mothers sharing conventional and eBooks with their 7-9-year-old children. Results did not reveal differences in recall quality, but there was significantly lower interaction warmth for eBooks compared to traditional books. They speculated that this is because children's posture for reading conventional books supported more shared activity. In a similar investigation, Munzer et al. [52] showed that parents and toddlers do not verbalize or collaborate as much with eBooks as traditional books.

2.2 Illustrations in Children's Books

Early research showed that children prefer illustrations over photographs in books [26, 51]. Their preferences for illustrations are based on factors such as color, aesthetics, scenery, and their interest in the subject portrayed [47, 49, 86]. Joseph [35] emphasized the importance of depicting interesting and important incidents in illustrations, cautioning against oversized, gaudy pictures that divert from the story's main theme [78]. But studies have shown that children prefer moderately large illustrations, which occupy 25% of the book's space, over smaller or medium-sized ones [5, 87].

The literature has also established that illustrations in children's storybooks are essential for both enjoyment and understanding of the stories [25, 32, 43]. Concannon [15] suggested that illustrations in preschooler's books not only convey the story's theme but also maintain young children's attention and serve as motivational elements. Hladíková [32], Schwarcz [74, 75] proposed that illustrations have a psychological impact on children, suggesting that the illustrations children encounter in books teach them how to deal with real-life problems, how to model their lives, and contribute to their development into adults. According to Hermanto [31], illustrations conveying moral messages can enhance emotional, spiritual, and intellectual intelligence in children.

Research by Brookshire et al. [7] demonstrated that illustrations improve story comprehension for first and third graders. A subsequent study with elementary school children confirmed this and found that it also enhances their retelling ability [55]. Therefore, Tursunmurotovich [83] emphasized illustrations as "*the most important element*" in children's books. In a follow-up study, Tursunmurotovich et al. [84] noted that illustrations enhance preschoolers' understanding of fictional worlds. Galda and Short [27] suggested that illustrations can also improve children's visual literacy, enabling them to analyze and think critically about visual images.

Edmonds [24] discussed the lack of racial diversity in illustrations and the importance of presenting pluralistic images to children since early childhood is the time when we form our racial identities and attitudes. Similarly, Roethler [69] addressed the lack of racial diversity and negative portrayals of persons of color in illustrations, which impact children's understanding of their societal place. Additionally, Gooden and Gooden [29] highlighted the underrepresentation of females in children's literature and their often biased portrayal, which can affect children's perception of women's roles.

2.3 Learning with eTextbooks

Some studies have investigated the impacts of eBooks and eTextbooks on learning outcomes. Hsiao and Chen [34] found that task-technology fit and mobile learning self-efficacy influence third-grade students' intention to learn with eBooks. Reich et al. [67]

concluded that preschool children learn equally well with eBooks, if not better than traditional books. However, Ross et al. [71] discovered that eBooks negatively affect 7-year-old children's comprehension but increase emotional engagement. Our research differs from existing studies as it does not explore the impact of eBooks on children's reading experiences, performance, or preferences. Instead, we focus on assessing whether incorporating meaningful animated illustrations can enhance children's reading experiences, performance, and preferences.

Studies have also explored the impact of animated illustrations on learners' perceptual and cognitive performance. Meta-analyses of these studies have identified a slight advantage in using animated illustrations over static ones [6, 9]. However, some studies argued that animations are significantly more effective when their portrayal of temporal changes is crucial for understanding complex concepts [37, 85]. This perspective is reinforced by a recent meta-analysis [61]. These findings, while insightful, differ from the focus of our work. Our research is situated in a passive learning context, as opposed to the active learning environments these studies address, where learners engage deeply with text and corresponding illustrations to learn new concepts, principles, laws, and relationships [16]. Additionally, most of the animations in these studies (76% [61]) are accompanied by narrations to mitigate novices' lack of domain-specific knowledge [58, 73, 77], making it challenging to isolate the effects of animations from those of narrations or to determine if they contribute equally to learning outcomes.

2.4 Learning with Animations

Ploetzner and Lowe [62] describe educational animations as visual representations that convey continuous change over time, consisting of modeled entities to visualize these changes exclusively. Ploetzner et al. [61] argued that static sequences and slideshows lack continuous change perception, videos of real-life do not use modeled entities, and simulations based on computational models differ from animations that visualize pre-defined changes, thus violating the sole visualization principle. While there has been no explicit investigation into the effectiveness of different animation effects like zoom, bounce, fly-in, appear, etc., on learning and information recall, research suggests that these effects need to be well aligned with the learning objectives for effectiveness [61].

A different line of research explored the cognitive processes involved in learning through animated illustrations to develop theoretical models [46, 81]. de Koning et al. [20] critiqued these models for not being explicit enough about the perceptual processes crucial for initially distinguishing between relevant and irrelevant information. They introduced a new framework that organizes the functions of cueing in animations into directing learners' attention to facilitate the selection and extraction of crucial information, highlighting the key topics of instruction and their organization, and making the connections between elements clearer to aid in their integration. Lowe and Boucheix [41, 42], meanwhile, focused on the initial perception-based phases and proposed a framework involving perception-based extraction of event units, assembling event units into regional structures, recognizing these regional structures, differentiating between their functions, and consolidating the mental model. These frameworks are specifically aimed at expository

illustrations that seek to explain complex concepts, principles, laws, and relationships, such as principles of fluid dynamics [63], the workings of an engine [62], or the mechanism of a piano [42]. Our research, in contrast, focuses on narrative illustrations that support text. Relevantly, Ploetzner and Lowe [62] reviewed the variety of expository animations used in learning research, highlighting the absence of a uniform standard. Instead, animations can range from brief slideshows to extensive, detailed sequences with varying frame rates (such as, slowmation [33], a technique that presents animations at a slow pace of 2 frames per second to illustrate concepts or narrate stories), offering different degrees of user interaction, either as standalone resources or as part of complex multimedia environments [62].

Recent research has also explored the use of machine learning tools to automatically generate animated visualizations, particularly diagrams and flowcharts, directly from text [23]. There have also been investigations into using large language models (LLMs) for transforming static illustrations into animated versions in response to user prompts [82]. However, these areas of study fall outside the scope of our current work.

2.5 Designing eBooks for Children

There is a limited body of research on eBook design for children. Colombo and Landoni [10], Culén and Gasparini [18] advocated for co-designing eBooks with children to enhance engagement. In a subsequent study, Colombo et al. [13] investigated factors that make eBooks more engaging for 9-11-year-old children. They emphasized the importance of designing eBooks to be flexible, enabling children to customize their reading experience based on their skills and preferences, maintaining a balance between reading challenges and individual abilities. Landoni [40] also encouraged investigating the effects of different eBook features on user experience. In a different work, Bu et al. [8] demonstrated that multi-sensory illustrations in eBooks, when combined with interactivity and auditory feedback, enhance emotional interaction and context understanding among 5-8-year-old children. They, however, did not provide a clear identification of the specific sensory stimuli responsible for the observed effects in their study.

Ryokai et al. [72] developed a multi-modal composition and storytelling tool that allowed 4-10-year-old children to record their facial expressions and create animated stories with these videos and their drawings. Results indicated that the tool enable collaboration, play, and meaningful manipulation of story elements by children. Dalla Longa and Mich [19] conducted a pilot study to explore the impact of animated illustrations on elementary school students' reading comprehension and found that those who did not use animated illustrations had a better understanding of the story.

3 USER STUDY

We conducted a mixed-design study to investigate the effects of different types of illustrations on children's engagement and enjoyment with eBooks, their recall of information from the stories, as well as their preference for the illustrations. Specifically, we studied the following illustration types (Fig. 1):

- (1) **Static illustration**, which can be drawn in various styles [48, 56], represents key events in the story. In this work, we

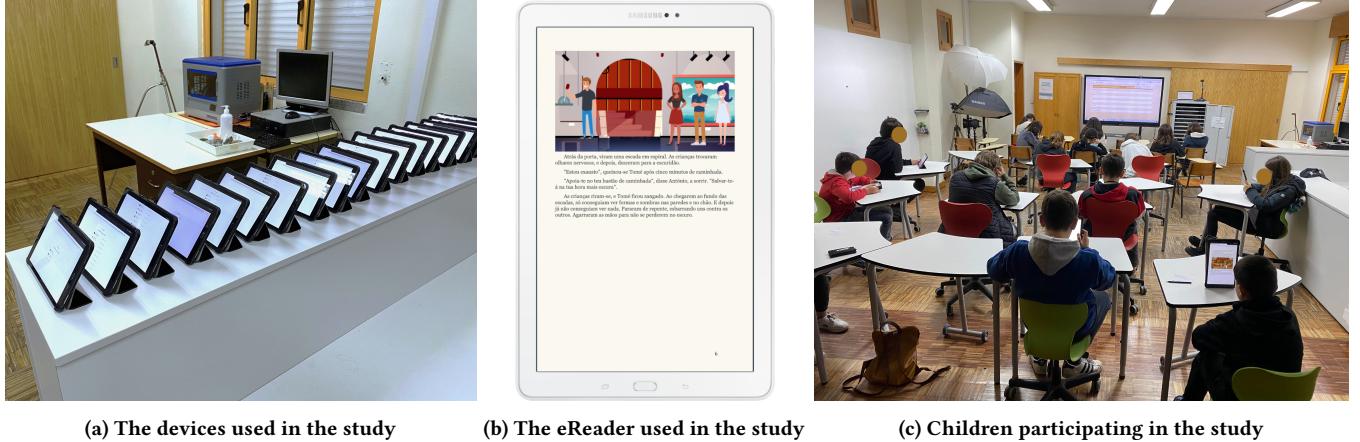


Figure 2: The devices, custom application, and classroom used in the user study.

used a modern illustration style known as digital or vector illustrations [2].

- (2) **Basic animated illustration** also represents a significant event in the story, but animates the drawing to show “how” the event took place. In this work, we only use simple motions and transitions to animate the illustrations.
- (3) **Focused animated illustration** extends a basic animated illustration by drawing the viewer’s attention to a specific character, object, or incident by using additional motion, transition, or zoom-in effects.

These three distinct types of illustrations were selected based on the characteristics of animated illustrations described by Ploetzner and Lowe [62]. The first illustration is not animated (static), serving as a baseline. The second type (basic animated) includes dynamic attributes such as motion and growth but does not explicitly depict continuous change. In contrast, the third type (focused animated) draws the viewer’s attention to a specific character, object, or incident, or illustrates continuous change over time, facilitating the development of a more comprehensive mental model of the depicted scenario.

3.1 Participants

We initially recruited 37 grade-6 students from three classrooms. However, many students were unable to attend the second day of the study due to a sudden snowstorm warning issued by the authorities, and their data had to be excluded from the analysis. To maintain equal group sizes, we also excluded data from four randomly selected students, resulting in a total of 18 participants in six groups. Their ages ranged from 11 to 12 years ($M = 11.2$, $SD = 0.4$), with eight identifying as female and ten as male. All of them were familiar with tablet eReader applications, as they frequently used them in class, and they were smartphone owners.

3.2 Apparatus

We conducted our user study using multiple Samsung Galaxy Tab A 10.1 touchscreen tablets ($254.2 \times 155.3 \times 8.2$ mm, 525 g, 2GB RAM) running Android 11 with a 1200×1920 pixel resolution,

connected to the school’s Wi-Fi network. These tablets were familiar to students as they were regularly used in classrooms. We developed a custom eReader application, resembling a typical tablet eReader app (Fig. 2b), which automatically recorded performance metrics. The eReader was built with HTML, CSS, and JavaScript, running on a Node.js backend. It featured a pale yellow (#FBF9EF) background, used Georgia typeface in black at 29 pixels with a line height extended by 120% [17, 45], and adopted a single-column format. Illustrations matched the column width [5, 87]. It allowed page-turning by swiping left or right with corresponding animations and sound effects, following current practices [59].

3.2.1 Stories for the eReader. We authored three original stories instead of using existing ones to avoid potential familiarity bias among children. To create these stories, we enlisted the assistance of a high school student (16 years, female) with creative writing expertise. She had creative freedom as long as the stories fell within the adventure genre (known to be popular among children [54]) and featured gender-balanced [29] and racially diverse [24, 69] protagonists. An experienced researcher with creative writing background served as the editor to ensure relatable elements, consistent plot-lines, and age-appropriate content. The resulting stories feature four school friends (two female, two male) embarking on secret missions with the assistance of a sentient sunflower. Although the stories share characters, their plotlines are independent, allowing readers to approach them in any order. Each story is of similar length ($M = 9,929$ characters, $SD = 1,423$), which is equivalent to approximately ten eBook pages.

We assessed the age-appropriateness of the stories through two methods. Firstly, we employed a text readability algorithm [50], which categorized the stories as having “high readability” at levels 6-7, suitable for children aged 11-13. Secondly, we consulted the class teachers of the three participating sections (2 female, 1 male, $M = 45$ years, $SD = 6$) with an average of 19 years of teaching experience ($SD = 6$). They read the stories and confirmed their appropriateness for their students, requiring no modifications.

3.2.2 Illustrations. We generated illustrations (Fig. 1) using stock vector graphics from Shutterstock.com, acquired with standard

licenses. These illustrations were full-color, with animated illustrations ranging from 2.5 to 4.9 seconds in length and played in a loop. In total, we created 27 illustrations, distributed across the three stories, three events per story, and three illustration types, with varying durations to prevent potential biases. We established a static illustration condition as the baseline in the study and did not include a no-illustration condition, as the literature already supports the benefits of illustrations on children's reading performance and experience.

We have made the stories in both English and Portuguese, and respective quizzes and illustrations publicly available for download² to encourage replication and further research.

3.3 Design

We employed a 3×3 mixed-design for our user study, with one between-subjects independent variable, *group*, consisting of three levels (groups 1, 2, and 3), and one within-subjects variable, *illustration*, featuring three levels (static, basic animated, and focused animated). Students were assigned to groups for the sole purpose of counterbalancing the stories and the three types of illustrations, ensuring that all students experienced all three stories and illustration types (three test conditions) once during the study. To minimize stress and fatigue effects, we introduced the three test conditions on separate days. This design allowed us to collect data from 6 students × 3 groups × 3 illustrations, totaling 54 data points, without interference between test conditions. Teachers assisted in assigning students to groups, initially dividing them into three factions based on their schedules and then adjusting student placements to ensure comparability in terms of reading comprehension skills. The groups also exhibited similarity in age and gender ratio. The study employed a questionnaire to gather children's preferences regarding their favorite stories and the types of illustrations they would prefer in stories and textbooks, and automatically recorded the following performance metrics:

- **Time per story** (seconds) indicates the average time children spent on a story, from opening it to reaching the questionnaire page. It serves as an engagement indicator, aligning with previous findings that children engage more when they spend more time with books [70, 88].
- **Revisit rate** denotes the average number of times children revisited previous pages while reading a story. It serves as an indicator of confidence, as previous research suggests that children tend to re-read or re-scan text when they lack confidence in their comprehension [38, 91].
- **Recall rate** represents the average number of correctly recalled information from the stories and illustrations, measured by the average number of correctly answered multiple-choice questions by the children.

3.4 Procedure

The study was conducted in a secondary school, with consent obtained from the school, students, and parents. The sessions took place on different days, with a maximum three-day gap in between. Both stories and illustrations were counterbalanced between groups.

²The stories, quizzes, and illustrations used in the study: https://www.theiilab.com/resources/Stories_Illustrations.zip

Students of each group participated together in a classroom setting. During the initial session, we introduced the custom eReader to students, despite their familiarity with popular eBook readers. We loaded the assigned stories and illustrations onto their tablets, starting from the title pages. Children were free to take their time reading the stories, with most completing them within 30 minutes. They could revisit previous pages as needed and proceed to a quiz at the end of each story.

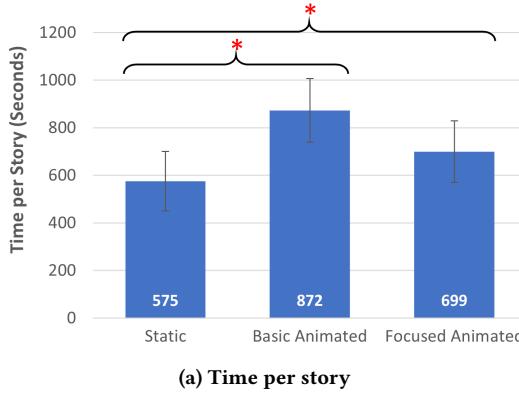
The quiz featured two multiple-choice questions for each event depicted in the illustrations, totaling six questions per story. Students earned points for correct answers, but their scores were not disclosed to minimize anxiety. We emphasized that the study aimed to evaluate the eReader, not the students, to avoid performance pressure. Discussion of stories or questions with peers was discouraged, and sessions were monitored to prevent this. Backward page-turning was disabled during the quiz to prevent seeking answers. Questions were intentionally kept simple to isolate the effects of illustrations. For the same reason, we intentionally asked participants to recall trivial details that are not necessarily vital for the progression of the story. The questions were designed to focus on two types of information: details that were concurrently presented in both the text and the illustrations (referred to as "concurrent"), and details that were exclusively depicted in the illustrations without any corresponding textual information (referred to as "visual-only").

The second and third sessions followed the same procedure, excluding the initial demonstration. Following all study sessions, a post-study questionnaire and debriefing session occurred on the fourth day. Students selected their favorite stories and indicated their preferences for illustrations in storybooks and textbooks. They were also encouraged to provide feedback and comments. We concluded by debriefing them on our investigation into the effects of illustrations on reading performance.

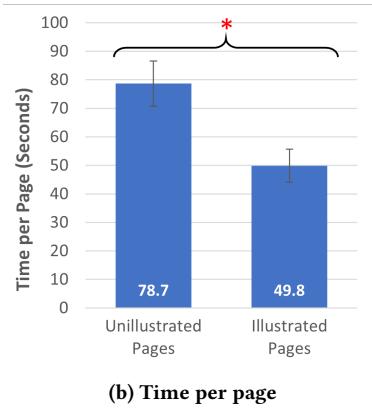
3.5 Results

We verified the residuals followed a normal distribution using a D'Agostino's K-squared test and established that the variances across populations were homogeneous by applying Mauchly's test. Therefore, our analysis employed mixed-design ANOVA. We used paired-samples t-tests to compare interactions with unillustrated and illustrated pages, and a Chi-Squared test for nominal questionnaire data. Effect sizes were reported for significant results (η^2 , Cohen's *d*, and Phi coefficient). Notably, group variations had no significant impact on the dependent variables, confirming the success of our counterbalancing approach.

3.5.1 Time per Story. An ANOVA revealed a significant effect of illustration on time per story ($F_{2,30} = 3.72, p < .05, \eta^2 = 0.05$). A Tukey-Kramer test found the difference between static and basic animated illustrations statistically significant. Evidently, children spent 52% more time with stories featuring basic animated illustrations than with stories featuring static illustrations. Fig. 3a presents the average time spent engaging with stories featuring the three types of illustrations. Additionally, a paired-samples t-test showed that children spent significantly more time with unillustrated pages than with illustrated pages ($t_{53} = 7.51, p < .0001, d = 1.0$). Fig. 3b depicts the average time children spent with unillustrated and illustrated pages.



(a) Time per story



(b) Time per page

Figure 3: (a) Average time spent per story, categorized by type of illustration, and (b) average time spent on pages with and without illustrations. Error bars represent ± 1 standard error.

3.5.2 Revisit Rate. An ANOVA failed to find a significant effect of illustration on revisit rate ($F_{2,30} = 0.84, p = .44$). Fig. 4a depicts the average revisit rates for stories featuring static, basic animated, and focused animated illustrations. However, a paired-samples t-test indicated a significant difference in the average revisit rates between unillustrated and illustrated pages ($t_{53} = 5.6, p < .0001, d = 0.8$). Children revisited the unillustrated pages 156% more often than the illustrated pages. Fig. 4b presents the average revisit of unillustrated and illustrated pages.

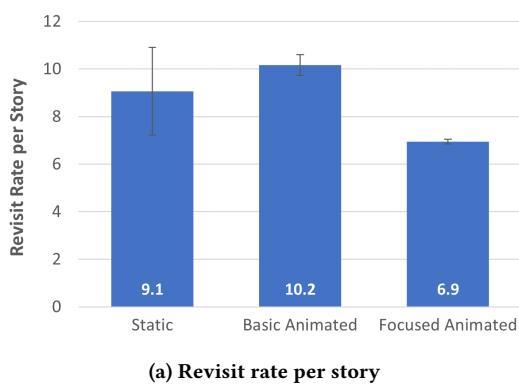
3.5.3 Recall Rate. An ANOVA revealed a significant effect of illustration on recall rate ($F_{2,30} = 4.57, p < .05, \eta^2 = 0.08$). A Tukey-Kramer test determined a statistically significant difference in recall rates between static and focused animated illustrations. The recall rate among children was 29% higher for stories with focused animated illustrations compared to those with static illustrations. Fig. 5a illustrates the average recall rates for static, basic animated, and focused animated illustrations.

Additionally, a paired-samples t-test revealed a significant difference in recall rates between concurrent and visual-only information ($t_{53} = 4.21, p < .001, d = 1.19$), with children being 56% more

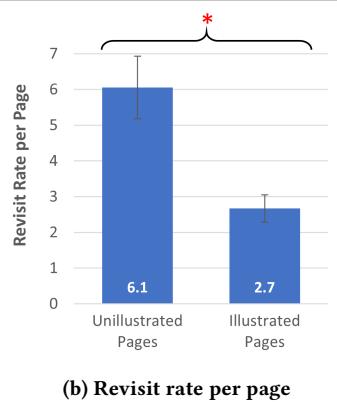
accurate in recalling concurrent information compared to visual-only information (1.9 vs. 1.2, respectively). Relevantly, an ANOVA highlighted a significant impact of illustration type on the recall rate of concurrent information across three types of illustrations ($F_{2,30} = 6.41, p < .005, \eta^2 = 0.16$). A subsequent Tukey-Kramer test showed that children recalled significantly more details with focused animated illustrations than with static ones (a 59% increase). Fig. 5b shows the average recall rates for concurrent information across the three types of illustrations.

However, an ANOVA did not reveal a significant effect of illustration type on the recall rate of visual-only information among the three types of illustrations ($F_{2,30} = 0.53, p = .59$). Fig. 5c displays the average recall rates for visual-only information across the three types of illustrations.

3.5.4 Enjoyment. A Chi-Squared test on responses to: “*Which story did you enjoy the most?*” revealed a significant relationship between enjoyment and the illustrations used in the stories ($\chi^2_{(9)} = 19.29, p < .05, \phi = 1.0$). Approximately 39% of children enjoyed the stories with focused animations, 28% enjoyed the stories with



(a) Revisit rate per story



(b) Revisit rate per page

Figure 4: (a) Average revisit frequency for stories, categorized by type of illustration, and (b) average revisit frequency for pages with and without illustrations. Error bars represent ± 1 standard error.

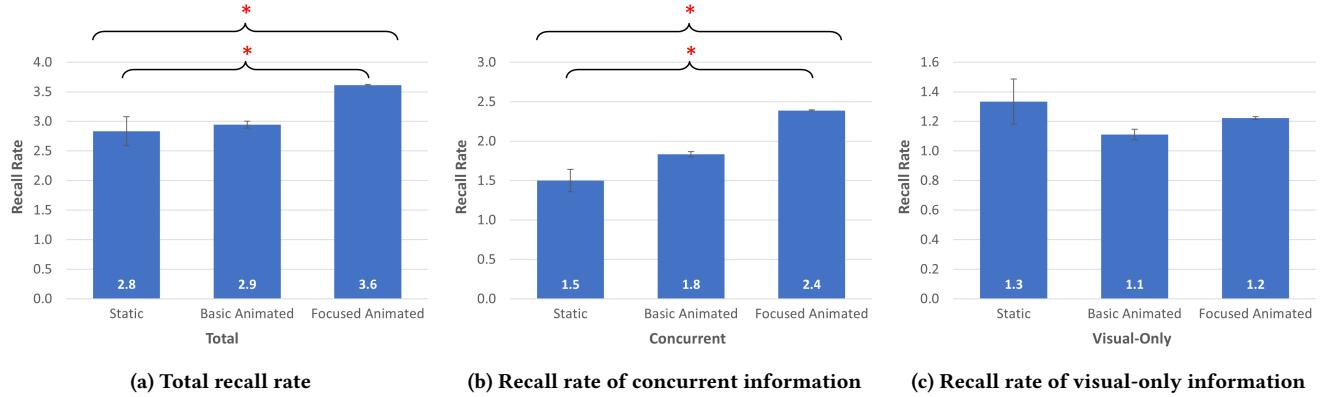


Figure 5: (a) Overall average recall rate, (b) recall rate for information presented in both text and illustrations (concurrent information), and (c) recall rate for information exclusive to illustrations (visual-only information) across different types of illustrated stories. Error bars represent ± 1 standard error.

basic animations, while 22% enjoyed the stories with static illustrations. The remaining 11% of children were undecided on this matter. Fig. 6 shows the average child enjoyment percentage for stories by illustration type.

3.5.5 User Preference. When asked which type of illustration they would prefer most in e-storybooks and e-textbooks, the majority of children did not differentiate between basic and focused animated illustrations, instead referring to both types collectively as “animated”. Therefore, for this analysis, we grouped both categories of animated illustrations together, comparing static illustrations directly with animated illustrations as a whole.

A Chi-Squared test revealed a significant impact of children’s illustration preferences on their choice of eBook type, story or textbook ($\chi^2_{(2)} = 8.67, p < .05, \phi = 0.49$). The findings indicate that 72% of children favored animated illustrations in storybooks, while 28% expressed no preference. Conversely, in textbooks, preferences were evenly split: 33% preferred animated illustrations, 33% had no preference for illustrations, and another 33% were undecided.

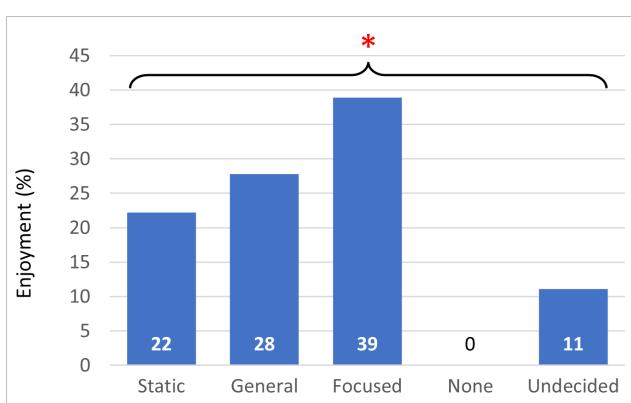


Figure 6: Average percentage of stories most enjoyed by children, categorized by illustration type.

Notably, static illustrations were not preferred by any participants in either category. Fig. 7 illustrates the average preference percentages for types of illustrations in stories and textbooks among children.

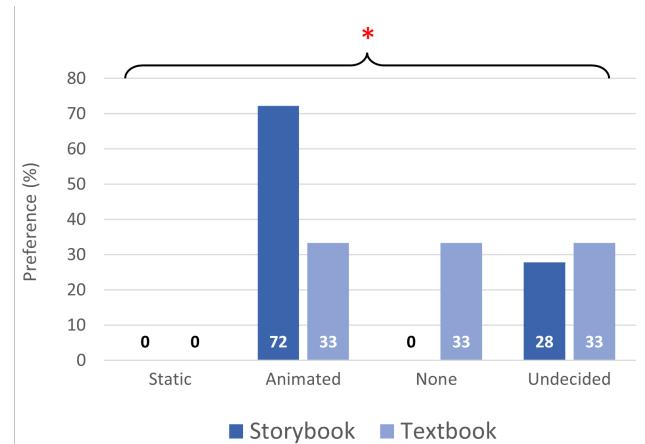


Figure 7: Average preference percentage for illustration types in stories and textbooks among children.

4 DISCUSSION

Results showed that children spent significantly more time with basic animated illustrations, 52% more, compared to static illustrations. While the average time spent with focused animated illustrations was also higher, 22% more than with static illustrations, this difference was not statistically significant. The increased time spent with animated illustrations suggests that children were more engaged with these illustrations and their respective stories. The fact that children spent less time with focused animated illustrations than with basic animated illustrations could be interpreted as the animated events helping them to grasp the changes and events more effectively than with basic animated illustrations [61, 62]. This assumption is supported by the lack of a significant effect of the story

type on time spent ($p = 0.55$) and user comments. One child (11 years, female) noted that she was really engaged in the story as "*the animated illustrations brought the story to life*". Another child (11 years, female) mentioned that it was easier to extract the necessary details from the focused animations because she could "*see what's happening in the story*". Further, although we did not video record the sessions for a post-hoc analysis of the children's behaviors, we noted during the study that the children were actively comparing the animated illustrations while reading.

When comparing pages with and without illustrations, the results showed that children spent significantly more time on pages without illustrations compared to those with illustrations. This outcome is anticipated because the illustrated pages had less text, and the illustrations acted as aids for comprehension. Research with adults has demonstrated that scanning text is quicker and requires less cognitive effort than reading for comprehension [53, 66].

The revisit rate for stories with focused animated illustrations was 24% lower compared to static illustrations and 32% lower than those with basic animated illustrations, though these differences were not statistically significant. However, a post-hoc Fisher's LSD multiple-comparison test revealed a significant difference in revisit rates between static and focused animated illustrations. Children's feedback indicated that the focused animations enhanced their confidence, reducing the need to revisit previous pages.

Similarly, when comparing pages with and without illustrations, children revisited the illustrated pages significantly fewer times, 56% less often, than the unillustrated pages. This tendency could also be attributed to their increased confidence in the information conveyed by illustrations over text. Without illustrations, children often revisited pages to reexamine details and enhance their understanding, a common strategy employed by readers to improve comprehension [38, 91].

The type of illustration significantly affected recall rates. Children's recall rate with focused animated illustrations was 29% higher compared to static illustrations and 14% higher than with basic animated illustrations. This indicates that the greater confidence in focused animated illustrations was well-founded. Post-study, children's comments supported this observation. For example, one child (11 years old, female) noted she could more easily recall details from the focused animated illustrations because "*it was easier to memorize more information*". A deeper investigation indicated that the increased recall rate was primarily due to children's recall of concurrent information (details presented in both text and illustrations). Children were 60% more accurate in recalling this type of information with focused animated illustrations than with static illustrations (statistically significant) and 33% more accurate compared to basic animated illustrations (not statistically significant). There was no significant effect of illustration type on the recall of visual-only information. This underscores the importance of providing key details in both text and illustrations rather than solely in one or the other.

The type of illustration significantly influenced enjoyment, with the majority of children favoring stories featuring focused animated illustrations (39%) or basic animated illustrations (28%). This finding is noteworthy as children were not explicitly asked to rate the stories based on the illustrations, instead, were asked exclusively about the stories. User responses indicated that children

perceived animated illustrations as enhancing the entertainment and fun aspects of the stories. For example, one (12 years, male) noted that "*the animations brought joy to the story*", while another (11 years, male) expressed a preference for animated illustrations because they were "*really fun*". However, a minority of children (22%) enjoyed static illustrations the most. The majority of children preferred having illustrations in storybooks, with approximately 72% believing that animated illustrations would enhance their reading experience. For instance, one child (11 years, female) stated, "*I would prefer having animated illustrations in storybooks because I like to see what's happening in the story*". However, children held mixed opinions about including illustrations in textbooks. About 33% of them wanted animated illustrations in textbooks, believing it would improve their understanding of the subject matter. One child (11 years, male) commented, "*animated illustrations can teach me how to do the exercises in textbooks*". Conversely, another 33% did not favor any illustrations in textbooks, as they perceived them as unhelpful for learning. The remaining 33% were undecided.

4.1 Design Recommendations

Based on the findings of this work, we recommend the following for children's eBooks:

- (1) Incorporate meaningful animated illustrations in both storybooks and textbooks to enhance reader engagement, increase enjoyment, and improve information recall.
- (2) Provide key details in both text and illustrations rather than solely in one or the other.
- (3) Offer an option to disable autoplay in storybooks, allowing readers to view illustrations in a static manner, as not all children may prefer animated illustrations.
- (4) Provide the option to remove illustrations in textbooks, as some children may not find them beneficial for learning, although more research is needed in this regard.
- (5) If incorporating animated illustrations is not feasible, include meaningful static illustrations to serve as aids for comprehension.

5 CONCLUSION

In a mixed-method study involving 11-12-year-old children, we examined the impact of three illustration types in eBooks: static, basic animated, and focused animated. Our findings indicated that focused animated illustrations led to the highest levels of performance and preference among the participants. Children not only showed greater engagement with focused animations but also reported increased confidence when interacting with them, which correlated with a significantly higher recall rate. Subjective feedback revealed a strong preference for animated illustrations, with 72% of the children believing that these illustrations enhance the reading experience in storybooks. However, views on the use of illustrations in textbooks were more varied, suggesting differing perceptions based on the content type.

5.1 Future Work

In the future, we aim to explore the potential of animated illustrations in STEM (science, technology, engineering, and math) education. Further, we plan to investigate the impact of illustrations

combined with auditory and tactile feedback, as well as narration, on children's reading experiences and performance. We also intend to extend this work to adults to assess their engagement and the effects on their learning.

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