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REGULAR PAPER

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Interactive illustration of collage for children with folktale e-book

Abstract It is always challenging to teach children foreign languages, due to the difficulty of learning and their short attention span. To address the challenge and take advantage of the popularity of touchable tablets and smartphones, we propose an educational folktale e-book (EFE-Book) application with an interactive illustratable tool. EFE-Book is developed to teach preschool children to learn foreign languages by telling folktales with illustrations. To encourage effective learning, EFE-Book provides an interactive collage tool that enables users to create collage-based illustrations by hand. We propose a Voronoi diagram based approach to model paper tiles for the development of EFE-Book. With EFE-Book, the user can create colored paper tiles and attach them to the predesigned sketch through touch interface, such as Apple iPad.

1 Introduction

Many mobile applications in various fields such as games, e-books and e-learning have been developed in recent years, thanks to the advancement of mobile technology. Touchable screens are now widely used for display devices such as smartphones and tablet PCs, making interaction between users and applications much easier. Many drawing tools are now available through mobile applications, for example, converting a photo into an image with artistic styles Capin et al. (2008); Kang et al. (2013).

For educational applications, the interaction and motivational elements are the most important, especially when the target users are children. In this sense, the stylization techniques with interaction can be an effective part of educational applications. So in this paper, we propose an educational folktale e-book (EFE-Book) for preschool children to learn foreign languages. Using the collage art technique, the EFE-Book provides an interactive illustratable tool and makes learning more effective and enjoyable.

The paper is organized as follows. Sect. 2, provides an overview of related work in mobile applications for e-learning and collage style rendering. Sect. 3 provides details of the EFE-Book with interactive illustratable tools. The results are discussed in Sect. 4. Finally, conclusion with a summary of our ideas and our future plans for further developments are discussed in Sect. 5.

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2 Related work

Mobile devices have been considered as a good supplementary to support both students and teachers by providing services that facilitate teaching, learning and education related administrative tasks, e-book and e-learning Lehner and Nösekabel (2002). Jacott (2009) explained applications and effectiveness of mobile learning, which provides useful, authoritative and comprehensive guidance for professionals in education. With its wide use and popularity, the smartphone has become a powerful mobile device for e-learning and e-book. In Godwin-Jones's article Godwin-Jones (2011), he explored the state of language learning applications, devices they run on, and how they are developed. Especially for language learning, Mori et al. (2011) proposed an interactive e-book application on smartphone. Their application was based on a conversational agent with animated character that asks questions or makes comments about the current page. These features made the book significantly more interactive and engaging when compared to static e-books. Compared with our application, the application of Mori et al. mainly focuses on the assist of learning, while our application focuses on motivating learning.

The collage stylization researches based on colored paper have mainly focused on generating colored paper tiles and placing them appropriately. Seo et al. (2001) proposed a method that converts an input image into a colored paper mosaic. In their method, the colored paper tiles are generated using the Voronoi diagrams Aurenhammer (1991). To replicate the torn paper effect, they applied the random midpoint displacement method. Gi et al. (2006) proposed a torn simulation-based colored paper mosaic method. The method tears off paper tiles from given colored papers, and places them on the most appropriate locations in an image. To locate tiles and minimize gaps and overlaps between tiles, they also proposed an energy function to avoid crossing edges in the image. By minimizing the energy function, a realistic colored paper mosaic image is generated. In contrast, Han et al. (2014) focused on the sequence in which tiles are placed, and proposed an approach that sequentially places each tile according to a customizable rule defined by parameters. This method was the first to enable placement of tiles along an edge, or to place tiles that have a similar color to previous tiles, by adjusting the parameters. In this paper, we partially employ some of the main ideas of the colored paper tile stylization proposed in the above studies.

Our preliminary study was published in Kang et al. (2016). In this paper, we have developed a new exam function for EFE-Book to enhance learning, and improved the illustratable tool with an assistance function. EFE-Book has also been expanded with a library which consists of a number of e-books with separate stories and illustrations. Moreover, we provide more experimental results which show that the illustratable tool in our application is effective for improving learning.

3 Development of EFE-Book with interactive illustratable tool for collage art

In this section, we give an overview of interfaces and functions of our e-book application for foreign language education, and propose an illustratable tool for collage art on the e-book.

### 3.1 The EFE-Book for preschool kids' learning foreign languages

3.1.1 Library

EFE-Book provides a library which consists of a number of e-books with separate stories and illustrations. When EFE-Book starts, it requires user to login to a server to access the library, as shown in Fig. 1a. If a user's account is validated, the server sends the content delivery network address to our EFE-Book, which then downloads encrypted data of each book from the address, and loads them onto the library (Fig. 1b). When the user selects a book on the library, a brief story with illustration is displayed as seen in Fig. 1c. Then the user can start reading and learning the book.

3.1.2 The EFE-Book

An overview of the EFE-Book is presented in Fig. 2. It consists of a cover page, several scenes, and exam page. Since too many scenes may shorten the span of preschool children, we limit the length of the scenes to 10. Each scene shows a representative illustration with a script which is a tale describing the scene. Figure 3 represents the layers of each scene. On the top layer, a menu bar and navigator buttons are located on the
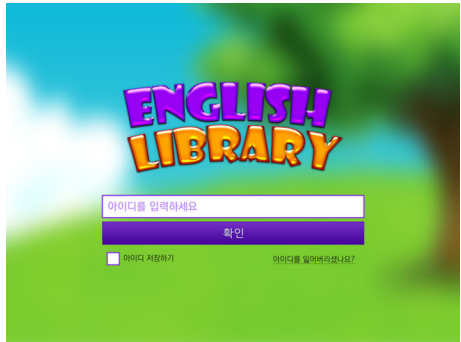
(a) Log-on display
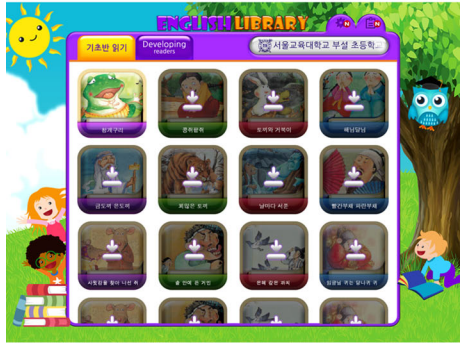
(b) The library of EFE-Books
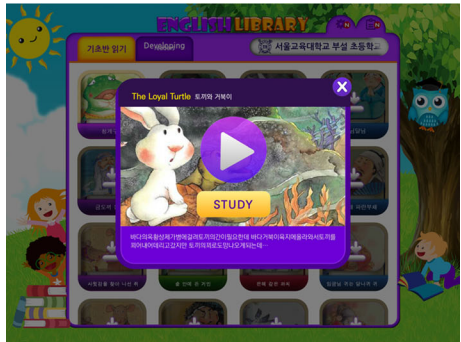
(c) An example of selected e-book

Fig. 1 Our application provides a library which allows access to various EFE-Books. This requires appropriate validation from server through log-on step

bottom and both sides of the scene, respectively. With navigator buttons, user can move to previous or next scene. The menu bar consists of several functions including replay which restarts the current scene, a table of contents that allows moving to a specific scene, an illustratable tool (more details in Sect. 3.2), and a movie function that plays all the scenes continuously. On the middle layer, a script is placed on a side of a scene. When a user enters a scene, a script is popped up. Then, a voice script is played with background music. At this time, the user may turn off the voice script to concentrate on reading. Moreover, the script can be replaced with another language using a language toggle button on the upper right corner of the scene. The EFE-Book provides scripts (both text and voice) with two languages, English and Korean. On the bottom layer, the illustration fills the entire scene. The illustrations in the EFE-Book are captured from original tale books, so they are static. However, we utilize fade in/out and zoom in/out effects to make the scenes dynamic when user enters each scene. At each scene, the user can create his/her own unique illustration with collage art through an illustratable tool from the menu. The detail of the illustratable tool is described in the next section.
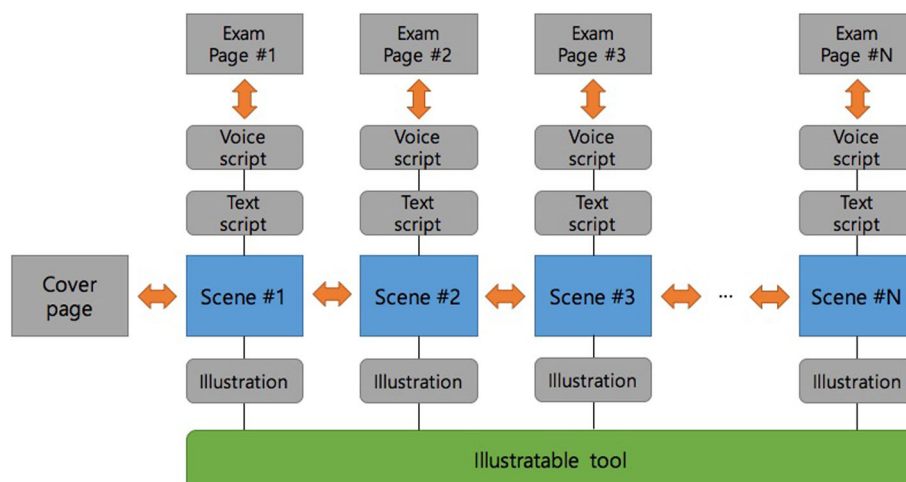
Fig. 2 Overview of the EFE-Book. The application consists of illustrated scenes with a short script. In each scene, a script is visually and auditorily played with the illustration. With a menu on each scene, user can interactively create illustration through the proposed tool for collage art
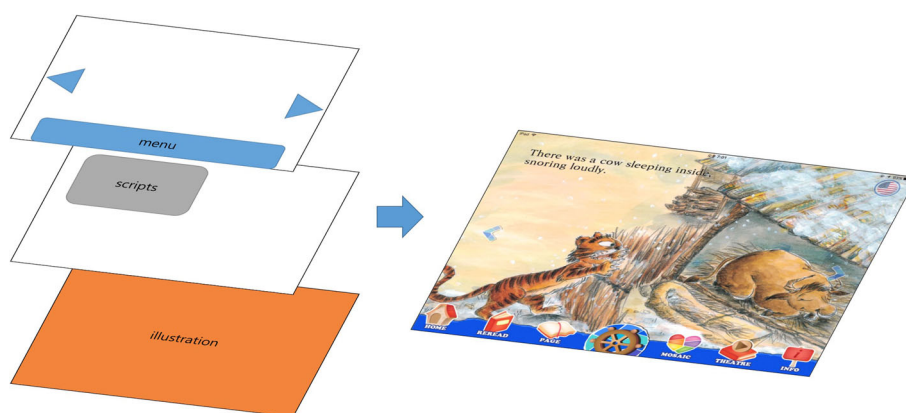

Fig. 3 Three layers of scenes. Menu bar and navigator buttons are located on the *top* layer; script is located on the *middle*; and illustration is located on the *bottom*

3.1.3 Exam page

After users finish reading each page of an e-book, our EFE-Book presents them an exam page which contains a multiple choice question in foreign language, as shown in Fig. 4. Because children have short attention span, we provide only one question per page. The questions are classified into two types: one is to choose an appropriate word for the blank space of a sentence presented in the book; and the other is to select a proper word for a given meaning which is described in native language (here Korean). After user selects an answer for each question, a correct answer is showed to tell user whether he/she has got it correct. When all questions are finished through an e-book, the total score is displayed. At this time, EFE-Book records user's last score into user's device, so that the user can compare their current score with the previous ones. Note that, to prevent user from being tested with same questions every time, EFE-Book randomly sample ten questions from its database of exam questions.

3.2 Interactive illustratable tool for collage art

When a user selects the illustratable tool from the menu bar, the screen changes into the interactive illustratable mode, as shown in Fig. 5. The screen in this mode consists of two panels; a white canvas with a
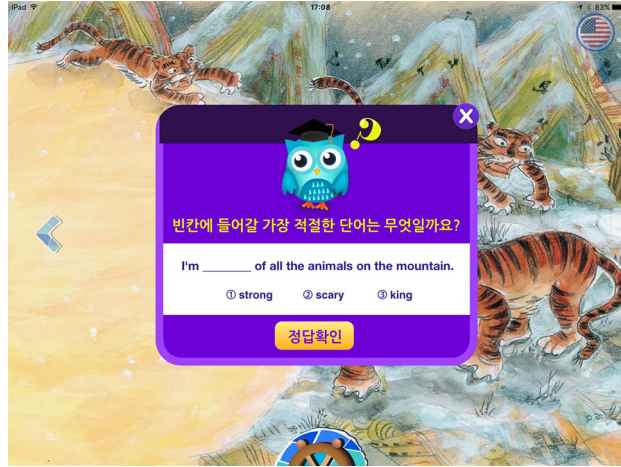
Fig. 4 Exam page. After reading each page, users are provided a question to test their study in foreign language

Fig. 5 Interactive illustratable mode

sketch on the right hand side panel, and a colored paper including a color selection tool on the left hand panel. On the canvas, the predesigned sketch of an illustrated character is located. The object is not filled with colors, so that user can fill it with colored paper tiles. When user touches the colored paper on the left hand panel and drags it to canvas, a small colored paper tile is torn out from the colored paper, and moves along to the trajectory of touched finger. Subsequently, the user can attach it to appropriate position on the canvas by keeping dragging. The color selection tool may be used for changing colors.

3.2.1 Modeling colored paper tiles

When user enters the interactive illustratable mode, the colored paper on the left panel is pre-divided into many small tiles. To divide the colored paper into tiles, we employ the Voronoi diagram Hoff et al. (1999) as shown in Fig. 6. A Voronoi cell C_i is defined using its pixel c, as shown in following equation.

$$C_i = \{c \in C_i | D(c, S_i) < D(c, S_j)\} \text{ for all } j, \tag{1}$$

where S_i is the site of C_i and D is a Euclidean distance function.

For rectangular colored paper on the left hand panel, we generate the initial Voronoi diagram by randomly inserting seed points, and relax the distribution of the seed points using the Lloyd's method Lloyd (2006) to obtain uniform sized Voronoi cells. The colored paper tiles are then created by converting each cell into polygon and filling them with selected colors. Although the colored paper is divided into tiles, this is not visible on the panel, as each tile is seamlessly positioned without any gap between tiles.
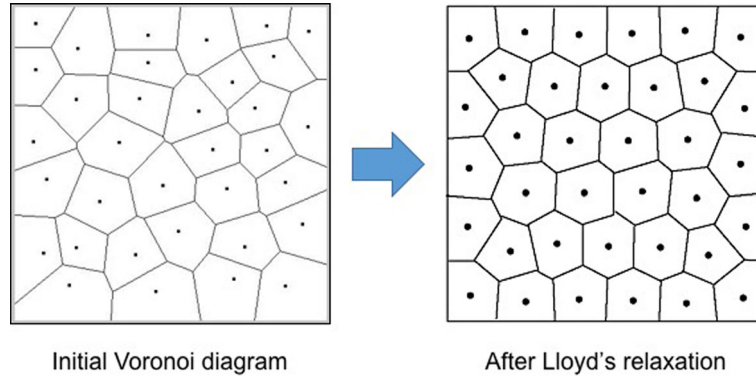
Initial Voronoi diagram   After Lloyd's relaxation

Fig. 6 Dividing *colored* paper into small tiles with the Voronoi diagram and the Lloyd's relaxation method. Each cell of the Voronoi diagram is used to create *colored* paper tiles
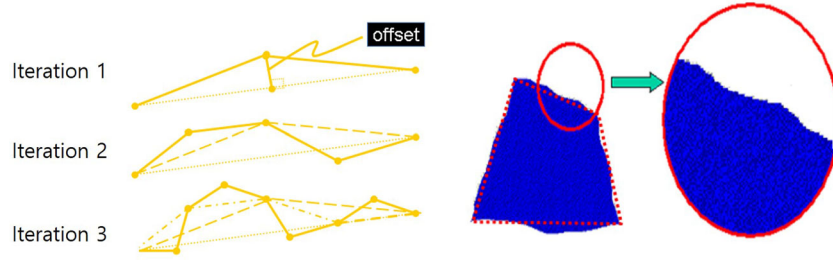

Fig. 7 Random midpoint displacement algorithm for torn paper effect
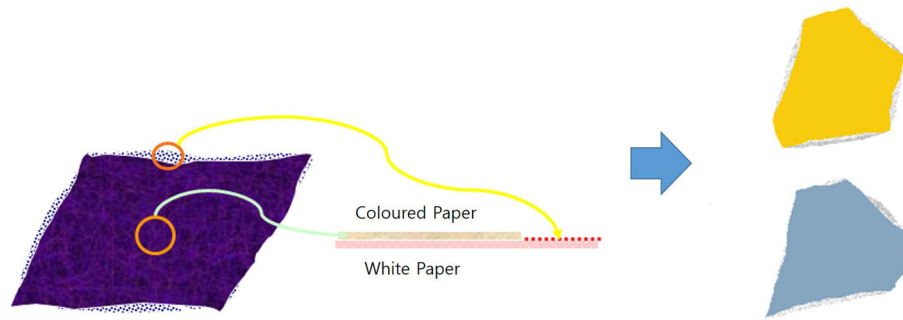

Fig. 8 Representation of the realistic torn paper effect. An additional *white* paper is added under the tile, and the random midpoint displacement algorithm is applied separately

3.2.2 Simulating torn paper effect

In the colored paper collage art, each tile has unique torn paper effects on their edges. We employ the random midpoint displacement method to simulate the torn effect. On each tile's edge, we select a midpoint, and subdivide the edge into two segments on that midpoint. The midpoint is then randomly displaced along a direction perpendicular to the edge. This is achieved by applying the following equation which calculates the randomly displaced midpoint:

$$f(p_1, p_2) = \frac{1}{2}(p_1 + p_2) + r v_p \tag{2}$$

$$v_p = R_{90} \overrightarrow{p_1 p_2}, \ R_{90} = \begin{bmatrix} 0 & -1 \\ 1 & 0 \end{bmatrix}, \tag{3}$$

Fig. 9 Tile location assistance function. When user drags a paper tile (*red circle*) from the colored paper panel, two of appropriate locations (*blue circle*) appear to assist locating the tile
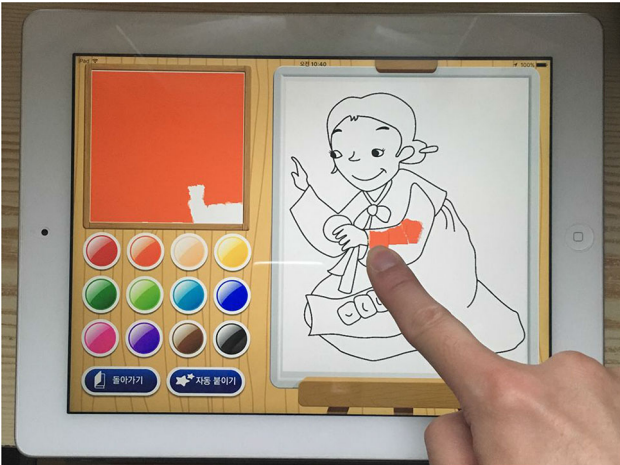

Fig. 10 EFE-Book on Apple iPad

Fig. 11 Procedure of EFE-Book. While reading and listening to the book, user can create illustration through our interactive illustratable tool

where p_1 and p_2 are the points on both sides of an edge and r is a random value within $[-t : t]$ which adjusts the range of displacement offset. In this study, we use $t = 0.25$ as the value of t. Until the subdivided segments reach third iteration, we perform these steps iteratively. This approach generates an irregular torn shape on the edge of tile as shown in Fig. 7. However, in real torn paper, we can observe that the white tissue of paper is revealed. To mimic this effect, under the original Voronoi cell of the tile, we add another white Voronoi polygon which has the same shape with the original cell, and apply the random midpoint displacement algorithm separately. As a result, we can get a torn paper effect similar to that in real torn paper as shown in Fig. 8. When user starts dragging tiles from the colored paper on the left panel, a torn paper effect is added to the edge of the tile.

3.2.3 Assistance of locating paper tile

To assist users to locate paper tiles easily onto appropriate position, EFE-Book provides an assistance function. When a user drags a tile from colored paper panel to canvas, the function indicates proper

positions of current tile. To implement this function, we employed the position-based tiling algorithm Han et al. (2014) which finds appropriate locations of tiles by considering the edges of the image and the shapes of neighbor tiles. Following the algorithm, we generate offset lines from the edge of sketch and the boundaries of pre-located tiles, and find the best two positions of current tile among the points on the offset lines. As shown in Fig. 9, according to the color and shape of dragging tile, the best two appropriate positions are displayed on the canvas, so that user can easily complete the collage.

4 Results

We implemented EFE-Book using OpenGL ES 2.0 Munshi et al. (2008) on Apple iPad's iOS environment, as shown in Fig. 10.

Figure 11 shows each step of illustration. User can navigate between scenes, and study a folktale with scripts written in a couple of languages including users' native language. Both text scripts and voice scripts are presented or played on each scene, so that user can learn the correct pronunciation of the foreign language such as English. At each scene, user can create illustrations through the illustratable tool. By touching and dragging tiles, the illustration of the paper collage art style can be generated. After the user
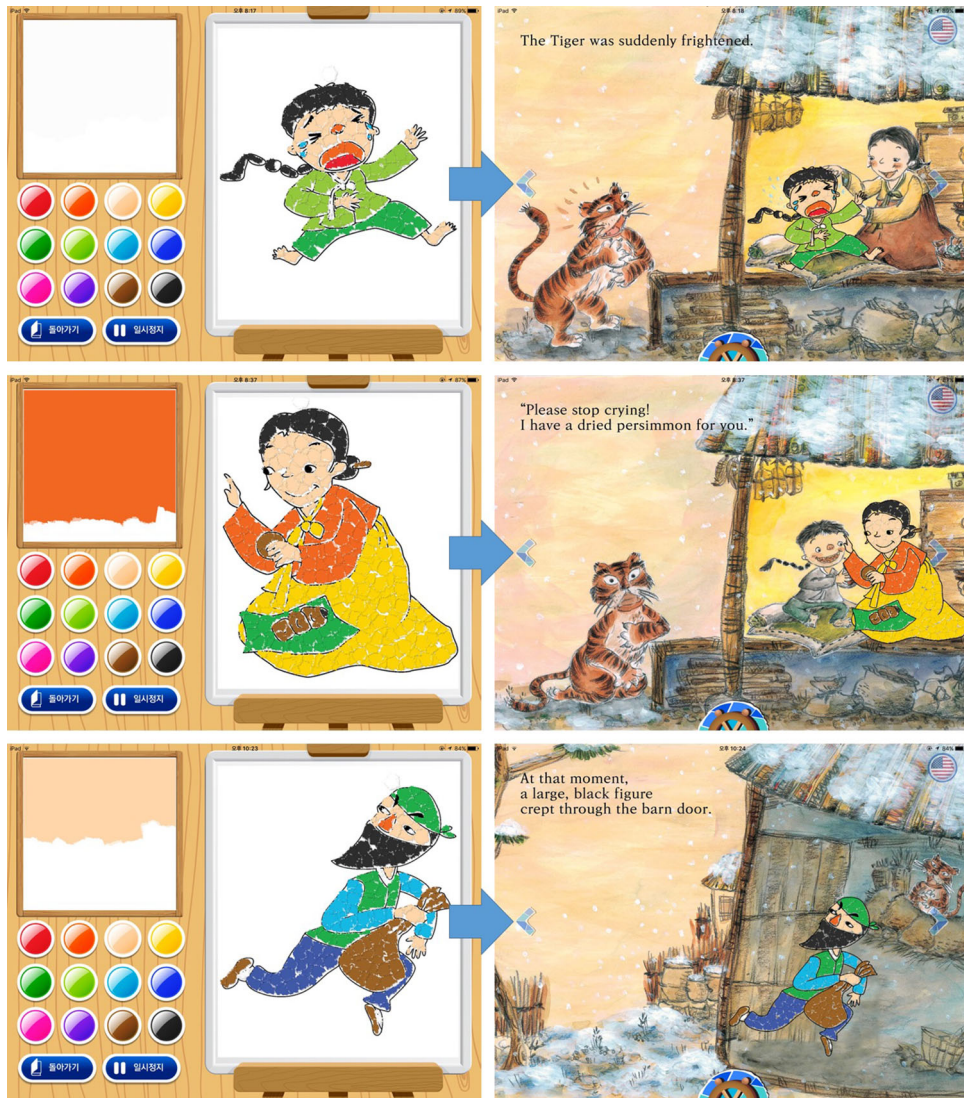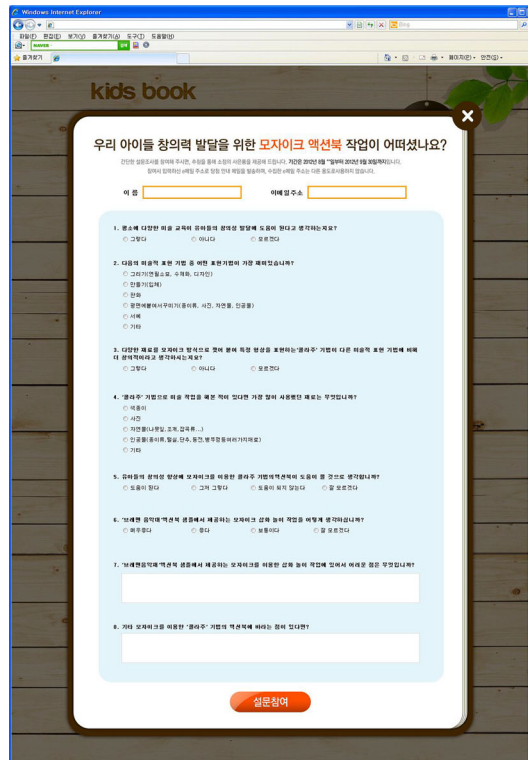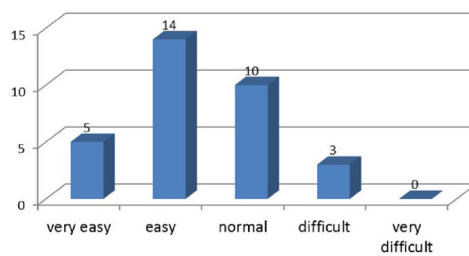

Fig. 12 Results generated with the EFE-Book. After the user finishes making collages, the result is displayed on the original scene of EFE-Book

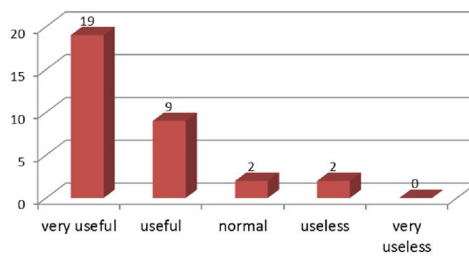**Table 1** Evaluation for the effectiveness of our illustratable tool

User id	Group A (w/ illustratable tool)												Group B (w/o illustratable tool)											
	a	b	c	d	e	f	g	h	i	j	St. dev.	Avg.	k	l	m	n	o	p	q	r	s	t	St. dev.	Avg.
Init. Score	8	4	5	6	4	5	6	7	6	6	1.25	5.7	5	5	6	7	4	5	8	9	6	7	1.55	6.2
Final score	10	8	6	8	7	8	7	7	8	9	1.14	7.8	4	7	7	9	7	6	7	10	8	8	1.64	7.3
+/−	2	4	1	2	3	3	1	0	2	3	1.20	2.1	−1	2	1	2	3	1	−1	1	2	1	1.29	1.1

(a) Survey form

(b) Results on usability

(c) Results on usefulness

Fig. 13 Evaluation results of a survey on usability and usefulness

finishes making collages, the result is displayed on the original scene of the EFE-Book, as shown in the Fig. 11, giving the impression that the user has created the illustration of the book. Figure 12 shows various collage results generated with the EFE-Book.

At the end of the application, we provided a link of webpage for a survey, as illustrated in Fig. 13a, to evaluate EFE-Book's usability and usefulness. For this survey, we asked the parents of children to answer a couple of enquiries about the usability and usefulness. In total, 32 users have responded. For the usability, we asked users how easy to use our application was. As shown in Fig. 13b, most of users responded that our application was relatively easy to use. According to users' comments on the survey, most children were very interested in doing collage with the tool, so that they read our EFE-Book to perform collage. There were a few minor comments about usability. However, because the size of tile was constant, it was difficult to locate tiles on narrow region. To overcome this, we will provide tile size control module in future version. For the usefulness of the tool, the question is how well our interactive illustratable tool on the EFE-Book helps in attracting children for studying foreign languages. As shown in Fig. 13c, most of the users agreed that the tool was useful for children's learning.

To evaluate the effectiveness of our illustratable tool for learning foreign language, we compared users' initial score (of the exam provided in EFE-Book) with the score which was recorded two weeks later. To do so, we first recruited 20 users who have 7–8-year-old children from online community. Then, we provided them our EFE-Book with same content. At this time, we divided users into two groups; one consists of 10 users who have EFE-Book with full functions (Group A in Table 1), and the other who also consists of 10 users was provided with another version of EFE-Book in which the illustratable tool is removed (Group B in Table 1). We asked them to let their children to do exams during first reading, and the results were collected to our server. Two weeks later, we asked them again, and compared the results with the previous one. As shown in the Table 1, a user group with the illustratable tool achieved 36.8% of improved rate while the other group without the illustratable tool did 17.7%. Thus, we could conclude that the illustratable tool is successfully to encourage users to learn foreign language.

5 Conclusion

In this paper, we discussed our proposed e-book application (EFF-Book) to teach preschool children foreign languages using devices such as smartphones or iPads. By utilizing the touch screen, our application provides an interactive illustratable tool for collage art. With folktale contents, our proposed illustratable tool can encourage the preschool children to concentrate more while learning.

As mentioned in Sect. 4, our collage illustrative tool provides only same sized tiles, so that tiles occasionally cannot fit narrow regions. To tackle this, we will develop tile size control module in future version. In addition, this work will be extended to other styles, e.g., paintings, drawings, etc. For this, we will study simulation of various styles with an intuitive interface.

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