A GOAL QUESTION METRIC (GQM) APPROACH FOR EVALUATING INTERACTION DESIGN PATTERNS IN DRAWING GAMES FOR PRESCHOOL CHILDREN

Dana Sulistiyo Kusumo, Mira Kania Sabariah, and Kemas Rahmat Saleh Wiharja

Software-Information and Data Engineering Research Group,School of Computing, Telkom University, Jl. Telekomunikasi no. 1, Bandung, Indonesia

E-mail: danakusumo@telkomuniversity.ac.id, mirakania@telkomuniversity.ac.id, bagindokemas@telkomuniversity.ac.id

Abstract

In recent years, there has been an increasing interest to use smart devices drawing games for educational benefit. In Indonesia, our government classifies children age four to six years old as preschool children. Not all preschool children can use drawing games easily. Further, drawing games may not fulfill all Indonesia's preschool children's drawing competencies. This research proposes to use Goal-Question Metric (GQM) to investigate and evaluate interaction design patterns of preschool children in order to achieve the drawing competencies for preschool children in two drawing Android-based games: Belajar Menggambar (in English: Learn to Draw) and Coret: Belajar Menggambar (in English: Scratch: Learn to Draw). We collected data from nine students of a preschool children education in a user research. The results show that GQM can assist to evaluate interaction design patterns in achieving the drawing competencies. Our approach can also yield interaction design patterns by comparing interaction design patterns in two drawing games used.

Keywords: *Interaction design pattern, goal-question metric, preschool children, drawing games*

Abstrak

Pada masa ini, terjadi peningkatan penggunaan aplikasi permainan menggambar pada perangkat pintar untuk tujuan pendidikan. Di Indonesia, pemerintah mengklasifikasikan anak-anak usia empat sampai dengan enam tahun sebagai anak usia dini. Namun tidak semua anak usia dini dapat menggunakan aplikasi permainan menggambar dengan mudah. Lebih lanjut lagi, aplikasi permainan menggambar tidak memenuhi semua kompetensi menggambar anak usai dini. Penelitian ini mengusulkan untuk menggunakan *Goal-Question Metric (GQM)* untuk menginvestigasi dan mengevaluasi pola desain interaksi anak usia dini dalam pencapaian kompetensi menggambar anak usia dini pada dua aplikasi menggambar berbasis Android: Belajar Menggambar dan Coret: Belajar Menggambar. Kami mengumpulkan data dari sembilan siswa Pendidikan Anak Usia Dini (PAUD) dalam sebuah *user research*. Hasil penelitian ini menunjukkan bahwa GQM dapat membantu untuk mengevaluasi pola desain interaksi dalam pencapaian kompetensi menggambar anak usia dini. Pendekatan yang kami usulkan dapat juga menghasilkan pola desain interaksi dengan membandingkan pola desain interaksi dalam dua aplikasi permainan menggambar yang digunakan.

Kata Kunci: *pola desain interaksi, goal-question metri, anak usia dini, permainan menggambar*

1. Introduction

Child computer interaction has been a fast-growing topic in the field of human computer interaction in recent years. Physically, four to six years old children could use wide range of gesture-based mobile application [1]. The government of Indonesia determines the education for four to six years old children as preschool education program. In recent years, the interest for creating drawing education application for children has increased. The drawing activity itself is full with stimulus for the growing process and development of the children. Beside that, the drawing activity gives visible and permanent traces that represents the characteristic of children. So it is very suitable to be done by the children [2]. By drawing, children could train the fine motor skills, creativity, imagination, concentration, memory, patience and the passion in learning. Drawing can also develop the children's capability in line with their talent and passion. And of course, by drawing, the children can know their surrounding world better [3].

Based on the previous empirical study, the children do not always understand about how to use tools and other movement in using a mobile application [4]. Therefore, the purpose of this research is to investigate the relationship between

children-game interaction and preschool children' drawing competencies. One of the main problems is the absence of the guidance in designing interaction patterns that is most suitable with the development stage of the children's fine motor skills. The interaction design pattern is a repeated solution for common usability problem in interface design [5]. The previous research [6] showed that interaction design pattern is one of the most important factor in designing a mobile application.

This research proposes a framework to analyze good interaction design pattern for drawing activities. We analyzed how children responded to several interaction design patterns and their interaction styles during drawing activities. After that, we defined the most proper interaction design pattern for children so that could meet the learning goal in preschool education program. Beside proposing the framework, we also assesed how the used interaction design patterns could meet the drawing competencies for children that is required by preschool education program. This assesment, in turn can provide information to the parents and the teachers of preschool children about how far an application can support children in mastering drawing competencies of preschool children. Interaction design patterns can be used by game developers as a guide to develop drawing game that will help the children in choosing the right features for drawing.

Related Work

Interaction design pattern is a design pattern for interaction between a user and a system [5]. Design pattern is defined as a repeatable solution for recurring software design problems [7]. Therefore, interaction design pattern is defined as a repeatable solution for recurring interaction problems. Interaction design patterns can be built from an existing application [8] following these processes: drafting existing interaction patterns, user research, testing interaction design pattern. Another approach using existing data to identify and analyze interaction design patterns use inductive and deductive approaches [9].

Goal Question Metric (GQM) is a software measurement framework for software products, processes and quality [10]. For measurement to be efective, we must have clear goals. Then, we detail goals into questions and develop metrics to answer the questions. So that, we can be confident that metrics used have strong relation with defined goals. GQM is used to detect design pattern using source code metrics combining with machine learning [11]. In recent literature, GQM has been used to guide a metric development for fulfilling

security goal in the cloud [12], analysis of the use of the C preprocessor in community and industry [13] and designing a mobile app for behavior change [14]. GQM is also used to recommend design patterns for software designers and developers [15]. In the HCI field, GQM help to develope a usability metric for mobile application [16].

We propose to use an approach to analyze existing applications to identify and analyze interaction design patterns from [8]. Furthermore, we use GQM in order to ensure that interaction design patterns identified meeting drawing competencies for preschool children. In this research, we first use GQM to set goal of the competency achievement and then empirically identify and analyze interaction design patterns from existing applications.

2. Methods

This research proposes to use Goal-Question-Metric (GQM) [10] for measuring interaction design pattern and analysing interaction design pattern of preschool children in order to achieve drawing competencies for preschool children. In this research, we asked 9 preschool children to complete tasks in two drawing games and then we collected interaction data (detailed in Data collection sub-section). The detail of GQM for this research is described as follows: **Goals** (achieving drawing competencies for preschool children using interaction design patterns); **Question** (are drawing competencies included in drawing games that are observed to preschool children? and how long does it take for children to complete relevant tasks in drawing games?); **Metric** (to clasify and map drawing competencies into observed drawing games and to measure time of interaction design patterns used by preschool children for completing drawing tasks).

This research also used the two first steps of interaction design pattern construction framework proposed by Pauwels et al. [8] for evaluating interaction design pattern: 1) collect interaction design patterns form an existing application; 2) user research. The aim of the first step is to investigate existing interaction design patterns and to find their problems. The aim of the second steps is to analyze interaction problems and to propose solutions. In the user research, participants were asked to used two drawing game, and then we investigated their interaction design patterns. In Pauwels et al. [8], they only use one application, but in our research, we used two applications. The aim to use two drawing games is to compare and find similarities in and probelems of interaction design patterns between two draw-

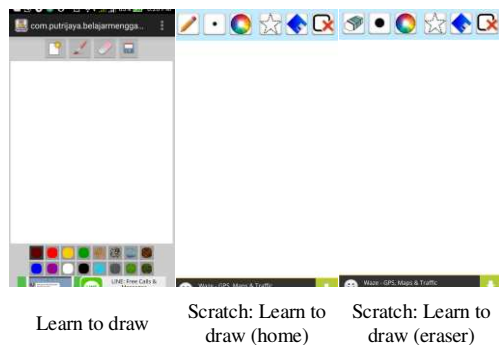Learn to draw   Scratch: Learn to draw (home)   Scratch: Learn to draw (eraser)

Figure 1. Two drawing games used in this research
(Learn to Draw and Scratch: Learn to Draw)

TABLE 1
MAPING AMONG THE TASKS, COMPETENCIES AND FEATURES IN THE DRAWING GAMES

Task	Competencies	Features
Drawing	- Making vertical, horizontal, curved (left/right), tilt (left/right), and circle - Imitating shapes - Completing manipulative motion for drawing shapes - Classifying things according to shape, color and size	- Brush - Eraser
Color selection	- Completing manipulative motion for drawing shapes - Classifying things according to shape, color and size	- Brush - Eraser - Color selection
Eraser	The same as drawing task	Eraser

TABLE 2
PARTICIPANTS' USER PERSONAS

Factor	First persona	Second persona
Personality	A child frequently uses gadget, such as: smartphone.	A child infrequently uses gadget, such as: smartphone.
Goals	Fulfill drawing competencies using observed drawing games	
Behavior	Drawing using papers, pencils, erasers and manual drawing tools. A child usually draws on a paper sketching using a pencil then coloring using coloring tools.	
Knowledge	-Able to understand letters - Able to understand numbers - Able to understand simple shapes and figures - Able to understand colors	

TABLE 3
PRESCHOOL CHILDREN'S DRAWING COMPETENCIES AS GOALS MAPPED INTO DRAWING GAMES

Goals
Goals of common competencies for all drawing games
To make meaningful scratch
To make vertical, horizontal, curved (left/right), tilt (left/right), and circle
To draw human complete with limbs
To draw and paint creatures lived and death
Goals of competencies specific to certain drawing games (not all games can provide these)
To thicken curved and straight lines
To imitate the basic shapes (circle, triangle and rectangle)
To imitate shapes
To match, show and mention more than 11 colors
Goals of competencies that are not fully supported by any drawing games
To paint, draw, make patterns, sewing, weave, pierce, and formed with a variety of tools and materials

ing games used. In this research, we used two drawing games (Figure 1): Belajar Menggambar (in english: Learn to Draw) and Coret Belajar Menggambar (in english: Scratch: Learn to Draw) downloaded from Google PlayStore. These games were selected because their features are simple and easy to use. Therefore, we could concentrate on measuring interaction design patterns and duration of game played.

Data collection in this research used a user research aiming to identify context and problems of interaction design in the games. By completing the user research, we can expect frequently important problems found when a user play a drawing game. In this stage, research participants were asked to complete some task scenarios using two drawing games. These task scenario had been mapped to Indonesia's preschool children's drawing competencies (Table 1). The aims are to yield interaction design patterns supporting the preschool children's drawing competencies. For the purpose of this paper, we only limit to discuss interesting interaction design patterns resulted from our proposed approach.

Preschool children were asked to complete the same task scenarios in two drawing games, then we interviewed them to investigate processes and challenges of completion of the tasks. We measured time completion for each participant when completing the tasks. In the data analysis, we compared how the tasks' completion in two drawing games to indentify problems and proposed solutions so that we can propose interaction design patterns.

We conducted a user research in a Kindergaden of Raudlatul Athfal located in village of Sukapura, Dayeuhkolot, Bandung, Indonesia. The sample method was random. In the begining, we asked all students to participate in our user research, but only nine students agreed to join the user research. The children were asked to complete the task scenarios as aforementioned in the Research methodology section. We used a Samsung Galaxy Tab A. First, nine children were asked to complete all the tasks and instructions in the first drawing game, Learn to Draw. After finishing the first game, then the children were asked to complete the same activies in the second drawing game, Scratch: Learn to Draw. During completing the game, we observed and noted interaction between the participants and games. Finally, we in-

TABLE 4
TASKS' COMPLETION TIME FOR LEARN TO DRAW (IN SECOND)

	1	2	3	4	5	6	7	8	9
Drawing	<5	<5	<5	5-10	5-10	<5	<5	<5	<5
Eraser	<5	5-10	<5	5-10	5-10	5-10	<5	<5	<5
Color selection	<5	<5	<5	5-10	5-10	<5	<5	<5	<5

TABLE 5
TASKS' COMPLETION TIME FOR SCRATCH: LEARN TO DRAW (IN SECOND)

	1	2	3	4	5	6	7	8	9
Draw-ing	<5	<5	<5	<5	<5	<5	<5	<5	<5
Eraser	-	>10	-	-	-	-	-	-	-
Color Select-ion	<5	<5	<5	<5	<5	<5	<5	<5	<5

terviewed their experiences completing the tasks.

The participants in our research were children age four to six years old. Based on Sabariah et al. [4], we classified two user personas for preschool children (see Table 2). In our user research, three children were in the first persona and six children were in the second persona.

The goals of GQM in this research refered to the Indonesian curriculum of preschool children's drawing competencies. However, not all competencies can be mapped into the drawing games because there are activites in the competencies that can not be represented into digital applications. Goals that were expected to be achieved are listed in Table 3.

When comparing the same competencies for both drawing games, we only investigated the same tasks for both games as follows: Making vertical, horizontal, curved (left/right), tilt (left / right), and circle; Imitating shapes; Completing manipulative motion for drawing shapes; Classifying things according to shape, color and size.

Basically, these competencies represent common and specific competencies for drawing games (Table 3). Table 1 maps between the tasks and competencies, which are goals in GQM, for the drawing games.

Table 4 and Table 5 show completion time for each task in Table 1. Time was measured from time needed for each kid to complete the tasks after instructions given. For example: in Table 4, child 4 needed 5 to 10 seconds to complete drawing task after an instuction given.

3. Results and Analysis

We compared time measurement in Table 4 and Table 5. Then, we correlated and analyzed data qualitatively using contextual information gathered from the observation and interview in the user research. In this section, we also highlight identified interaction design patterns as results of our proposed method.

Goal-Question-Metric (GQM) was used to analyze interaction design patterns for supporting goals acheivement, which are preschool children's drawing competencies. Table 1 shows the category of preschool children's drawing competencies mapped into the tasks and supporting features in the drawing games as the result of breakdown goal into question and metric. Therefore, the drawing games have achieved goals of our proposed GQM which common preschool children's drawing competencies are available in the drawing games (Table 1). However, each of the games supports competencies specific to certain drawing games (Table 3). For example, the game of Scratch: Learn to Draw supports the competency of thickening straight and curved line, but this competency is not supported by the game of: Learn to Draw.

Based on, interaction design pattern measurement (during observation of the user research), the children did not find the games difficult to play. Average time to complete the tasks was between 5 and 10 seconds (Table 4 and 5). There are two explanation about this average time. The first is the role of first participant, named Jugjug, who has experience playing similar games. Then, the other participants followed Jugjug's interaction patterns using the games. The second is simple user interfaces so that the participants could easily learn to use and make adaption with provided menus and features. This was supported by facts that the participants were faster to complete drawing and color selection tasks in the second game compared to the first game because the participants had better understanding of mental model for the patterns of drawing games from the first game.

We find that a good interaction design pattern separates all buttons in the main interface (**the first interaction design pattern identified as the result of our proposed method**). This pattern is shown in the Draw to Learn game, which drawing, eraser and color selection are separated. Meanwhile, in Scratch: Draw to Learn game, eraser button is only active when drawing button is pressed (Figure 1). Not all participants could understand this feature in Scratch: Draw to Learn game, so that almost all participants chose to not finish the eraser task (Table 5) and prefered to choose to press new menu to erase existing picture. We suggest to separate all these buttons (**the second pattern**) in accordance with the mental model of a user reflecting a real world

condition which the functions of drawing tools and eraser are separated.

We propose to use two games in this research to identify and analyze interaction design patterns. Compared to [8], the use of two application has benefits of speeding up to study existing interaction design patterns, finding problems and proposing solutions. The use of two application is relevant to A/B testing [17] aiming to choose better system design. By comparing two applications, we can check whether interaction design patterns, including their problems and solutions, exist in both applications or not. If an interaction design pattern exist in both applications we can take the better interaction design pattern among the same interaction design pattern. This can strengthen an interaction design pattern resulted from the analysis because there are common problems and solutions related to interaction between an user and a system. But, if an interaction design pattern only exists in one of two applications, then we can choose this interaction design pattern as a proposed interaction design pattern. For example, the competency of thickening straight and curved line can only be found in the game of Scratch: Learn to Draw (**the third pattern**). Therefore, relevant interaction design pattern for this competency is taken from the game of Scratch: Learn to Draw. Based on our empirical results, the first and second identified interaction design patterns are suitable for preschool children.

4. Conclusion

The use of Goal-Question-Metric (GQM) can assist to identify, analyze and evaluate interaction design patterns in drawing games. The goal is to achieve preschool children's drawing competencies using interaction design patterns. By formulating questions and metrics derived from the goal, it can yield a mapping of drawing competencies into features, tasks and interaction design patterns of the observed drawing games. Based on this research's findings, using our approach can yield interacton patterns. By using two applications, we expects to get more inter-action design patterns compared to Pauwels et al. [8] approach, which uses an existing application to identify and analyze interaction design patterns. However, to get best interaction design pattern, we suggest to use all stages in Pauwels et al. [8] approach. Because we only used two applications, we only got limited interaction design patterns. Therefore, we suggest to compare more applications to yield more interaction design patterns. We suggest that parents and teachers of preschool students can use and combine more than one drawing game in order to achieve all preschool children's drawing competencies. In addition, this can also be an opportunity for Indonesian's game developers to produce drawing games fulfilling all preschool children's drawing competencies through the use of interaction design pattern.

Acknowledgment

References

[1] A. Hiniker *et al.*, "Touchscreen Prompts for Preschoolers: Designing Developmentally Appropriate Techniques for Teaching Young Children to Perform Gestures," in *Proceedings of the 14th International Conference on Interaction Design and Children*, New York, NY, USA, 2015, pp. 109–118.

[2] N. Scheuer, M. de la Cruz, and J. I. Pozo, "Children talk about learning to draw," *Eur. J. Psychol. Educ.*, vol. 17, no. 2, p. 101, Jun. 2002.

[3] M. Fadlillah;, "Desain Pembelajaran PAUD: Panduan untuk pendidik, mahasiswa & pengelola pendidikan anak usia dini," 2012. [Online]. Available: http://library.fip.uny.ac.id/opac/index.php?p=show_detail&id=6866. [Accessed: 08-Feb-2017].

[4] M. K. Sabariah, V. Effendy, and M. F. Ichsan, "Implementation of Hierarchical Task Analysis for User Interface Design in Drawing Application for Early Childhood Education," *J. Educ. Learn. EduLearn*, vol. 10, no. 2, pp. 159–166, May 2016.

[5] D. A. Norman and S. W. Draper, Eds., *User Centered System Design: New Perspectives on Human-computer Interaction*, 1 edition. Hillsdale, N.J.: CRC Press, 1986.

[6] F. B. Leandro, A. Solano, and C. A. Collazos, "Proposing Interaction Patterns for Designing Videogames Supported in Smartphones," in *Proceedings of the XV International Conference on Human Computer Interaction*, New York, NY, USA, 2014, p. 41:1–41:2.

[7] E. Gamma, R. Helm, R. Johnson, J. Vlissides, and G. Booch, *Design Patterns: Elements of Reusable Object-Oriented Software*, 1 edition. Reading, Mass.: Addison-Wesley Professional, 1994.

[8] S. L. Pauwels, C. Hübscher, J. A. Bargas-Avila, and K. Opwis, "Building an interaction design pattern language: A case study," *Comput. Hum. Behav.*, vol. 26, no. 3, pp. 452–463, May 2010.

[9] N. Schadewitz and T. Jachna, "Comparing inductive and deductive methodologies for design patterns identification and articulation," presented at the International Design Research Conference IADSR 2007 Emerging Trends in Design Research, Hong Kong, 2007.

[10] V. R. Basili, "Software Modeling and Measurement: The Goal/Question/Metric Paradigm," University of Maryland at College Park, College Park, MD, USA, 1992.

[11] S. Uchiyama, A. Kubo, H. Washizaki, and Y. Fukazawa, "Detecting Design Patterns in Object-Oriented Program Source Code by Using Metrics and Machine Learning," *J. Softw. Eng. Appl.*, vol. 07, no. 12, p. 983, Nov. 2014.

[12] F. Yahya, R. J. Walters, and G. B. Wills, "Using Goal-Question-Metric (GQM) Approach to Assess Security in Cloud Storage," in *Enterprise Security*, Springer, Cham, 2017, pp. 223–240.

[13] C. Hunsen *et al.*, "Preprocessor-based variability in open-source and industrial software systems: An empirical study," *Empir. Softw. Eng.*, vol. 21, no. 2, pp. 449–482, Apr. 2016.

[14] P. Tikka, B. Woldemicael, and H. Oinas-Kukkonen, "Building an App for Behavior Change: Case RightOnTime," in *Proceedings of the Fourth International Workshop on Behavior Change Support Systems (BCSS2016)*, Salzburg, Austria, 2016.

[15] F. Palma, H. Farzin, Y.-G. Guéhéneuc, and N. Moha, "Recommendation System for Design Patterns in Software Development: An DPR Overview," in *Proceedings of the Third International Workshop on Recommendation Systems for Software Engineering*, Piscataway, NJ, USA, 2012, pp. 1–5.

[16] A. Hussain and E. Ferneley, "Usability Metric for Mobile Application: A Goal Question Metric (GQM) Approach," in *Proceedings of the 10th International Conference on Information Integration and Web-based Applications & Services*, New York, NY, USA, 2008, pp. 567–570.

[17] B. Hanington and B. Martin, *Universal Methods of Design: 100 Ways to Research Complex Problems, Develop Innovative Ideas, and Design Effective Solutions*. Beverly, MA: Rockport Publishers, 2012.