Evaluate of digital book criteria using fuzzy analytical hierarchy process

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Abstract. Recently, digital technology is developing rapidly. Digital technology also needs to be developed in the field of education, especially Digital Book. In evaluating digital books, stakeholders need appropriate criteria. Therefore, this study aims to evaluate the criteria of an excellent digital book by using a fuzzy analytical hierarchy process. A digital book evaluated is elementary school mathematics learning books by considering aspects of Azaz Pancasila. The criteria evaluation method uses a fuzzy analytical hierarchy process. Evaluation criteria used are easy to use, multimedia, interaction. The evaluation results of digital book criteria show that easy criteria have the highest importance. Furthermore, multimedia and interaction criteria have the importance of the second and third importance. This research implies that the selection of the right criteria can be a reference in the development of digital books.

1. Introduction
In the industrial revolution 4.0, the education sector must follow with technological developments. Improving the quality of education is carried out by integrating technology in learning activities [1]. One use of this technology is digital books. In this time, popular books switch to digital books [2]. It has advantages such as a variety of learning resources, a curriculum be adapted to students' learning motivation, and increasing information [3]. Learning by using digital books can support learning performance and motivate students to learn [4]. However, evaluations of digital books need to be carried out to find out essential criteria in digital books.

Several previous studies on the evaluation of digital book criteria have been conducted. Ramadan [5] evaluated the criteria of digital books using descriptive qualitative methods. The author used criteria such as the font type, font size, page layout, and background of digital books. De Jong and Bus [6] analysed digital book content based on multimedia aspects, interactive images, and interactive readability that used descriptive qualitative methods. Çalışkan, et al. [7] evaluated digital books from aspects of content, technology, layout, and interaction. They used qualitative methods to analyse.
Bozkurt and Bozkaya [8] assessed digital books using quantitative and qualitative methods. The criteria for digital books assessed were aspects of content, interface, interactivity, and technology. Fahmy, et al. [9] evaluated the quality of digital books based on ISO 9126. They considered aspects of functionality, reliability, usability, efficiency, and portability, and they used qualitative methods.

Based on previous research, generally, researchers have used descriptive qualitative methods to evaluate digital books [5-9]. In contrast to previous studies, this study uses the Fuzzy Analytic Hierarchy Process (AHP) in the evaluation of digital books. To our knowledge, no research uses FAHP to evaluate the criteria in digital books. FAHP is a method that is able to accommodate the uncertainty of perception, intuition and preference. Previous research only considers the value of "crisp" which only accommodates definite values.

Therefore, this study aims to evaluate the criteria for an excellent digital book using FAHP. FAHP is a secure method to use in evaluation. It is included in the category of multi-criteria decision making (MCDM). This research made a significant contribution in evaluating the evaluation criteria on digital books because the proposed FAHP method is the first MCDM method used for digital book evaluation.

2. Methods

2.1. Fuzzy Analytical Hierarchy Process (FHP)
This study proposes the FAHP method to evaluate the criteria and sub-criteria in digital books. The FAHP method was first proposed by Chang [10]. It is an easy to use method in assessment evaluation of the digital-book. The extent analysis method is a popular procedure for evaluating synthesis in Fuzzy AHP pairwise comparisons. The stages of extent analysis are explained as follows;

2.1.1. Determination of the value of the fuzzy synthetic extent. This procedure is used to obtain the synthesis value of an object, so the value of extent analysis M is shown as

\[ M_{gl}^{1}, M_{gl}^{2}, ..., M_{gl}^{m}, i = 1, 2, ..., n \].  \( M_{gl}^{j} \) (j = 1, 2, ..., m) is a triangular fuzzy number (TFN). The synthesis formula is presented in equation (1).

\[ S_i = \bigotimes_{j=1}^{n} M_{gl}^{i} \bigotimes \left[ \bigotimes_{j=1}^{m} M_{gl}^{j} \right]^{-1} \]  

To produce \( M_{gl}^{j} \), We need to carry out the addition operation of the fuzzy extent analysis M value for each triangular fuzzy number. The addition operation for each line is presented in equation (2).

\[ \mathbb{S}_{i=1}^{n} M_{gl}^{j} = \left( \mathbb{S}_{j=1}^{m} l_{ij}, \mathbb{S}_{j=1}^{m} m_{ij}, \mathbb{S}_{j=1}^{m} u_{ij} \right) \quad i = 1, 2, ..., n \]

Furthermore, equation (2) can also be written as in equation (3).

\[ \left[ \mathbb{S}_{i=1}^{n} M_{gl}^{j} \right] = \left( \mathbb{S}_{i=1}^{n} \mathbb{S}_{j=1}^{m} l_{ij}, \mathbb{S}_{i=1}^{n} \mathbb{S}_{j=1}^{m} m_{ij}, \mathbb{S}_{i=1}^{n} \mathbb{S}_{j=1}^{m} u_{ij} \right) \]

To obtain the inverse of equation (1), we can perform the arithmetic operations presented in equation (4).

\[ \left[ \mathbb{S}_{i=1}^{n} \mathbb{S}_{j=1}^{m} M_{gl}^{j} \right]^{-1} = \left( \frac{1}{\mathbb{S}_{i=1}^{n} u_{ij}}, \frac{1}{\mathbb{S}_{i=1}^{n} m_{ij}}, \frac{1}{\mathbb{S}_{i=1}^{n} l_{ij}} \right) \]

2.1.2. The comparison of TFN. This comparison is used for the weight value for each criterion. For 2 TFN numbers \( M_1 = (l_1, m_1, u_1) \) and \( M_2 = (l_2, m_2, u_2) \), if the value \( M_1 \geq M_2 \), the formula is presented in equation (5).

\[ V(M_1 \geq M_2) = sup \{ \min (u_{M_1}(x), u_{M_2}(y)) \}, y \geq x \]
For convex fuzzy numbers, the formula is illustrated in equation (6). The comparison of 2 TFN numbers is illustrated in Figure 1.

\[
V(M_2 \geq M_1) = \begin{cases} 
1; & \text{if } m_2 \geq m_1 \\
0; & \text{if } l_2 \geq u_1 \\
\frac{l_2 - u_2}{(m_2 - u_2) - (m_2 - u_2)}; & \text{other}
\end{cases}
\] (6)

\[
V(M_2 \geq M_1) = \begin{cases} 
1; & \text{if } m_2 \geq m_1 \\
0; & \text{if } l_2 \geq u_1 \\
\frac{l_2 - u_2}{(m_2 - u_2) - (m_2 - u_2)}; & \text{other}
\end{cases}
\]

**Figure 1.** Intersection between \(M_1\) and \(M_2\).

\(d\) is the ordinate point of intersection between \(\mu_{M_1}\) and \(\mu_{M_2}\). To compare \(M_1 = (l_1, m_1, u_1)\) and \(M_2 = (l_2, m_2, u_2)\), we require values from \(V(M_1 \geq M_2)\) and \(V(M_2 \geq M_1)\).

2.1.3. If the results of the fuzzy value (M) are higher than the k fuzzy value \(M_i\), where \(i = 1, 2, \ldots, k\), then we need to use the max and min operations presented in equation (7).

\[
V(M \geq M_1, M_2, \ldots, M_k) = \max \{V(M \geq M_1) \text{ and } V(M \geq M_2) \text{ and } \ldots \text{ and } V(M \geq M_k)\} = \min V(M \geq M_i), i=1,2,\ldots,k
\] (7)

Equation (7) assumes that:

\[
d'(A_i) = \min V(S_i \geq S_k) \text{ for } k = 1, 2, \ldots, n: k \neq i
\] (8)

Therefore, the weight vector is determined based on equation (9). \(A_i (i = 1, 2, \ldots, k)\) is n element.

\[
W' = (d'(A_1), d'(A_2), \ldots, d'(A_n))^T
\] (9)

2.1.4. Normalizing vector values. This procedure is carried out to get the weight of non-fuzzy numbers. The normalization formula is formulated in equation (10).

\[
W = (d(A_1), d(A_2), \ldots, d(A_n))^T
\] (10)

2.2. Data collection

A case study was conducted on the evaluation of digital books in elementary schools in the Sukun sub-district, Malang City, Indonesia. This study used three respondents to assess the criteria and sub-criteria for evaluating digital books. They were one elementary school teacher, one education expert, and one elementary school student. The evaluation was conducted on an elementary school mathematics learning electronic book that considered aspects of Pancasila characters. The criteria used were easy to use, multimedia, and interaction. The selected criteria and sub-criteria were based on literature review and focus group discussion. Table 1 presents the criteria and sub-criteria in evaluating digital books. Furthermore, three respondents conducted focus group discussions to
determine the importance level of the criteria and sub-criteria. The importance scale used the triangular fuzzy number (TFN) that is presented in Table 2. The results of focus group discussions on the digital book Criteria and sub-criteria are presented in Table 3-6.

| Criteria                | Definition                                                                 | Sub-criteria                                                                 | Reference |
|-------------------------|-----------------------------------------------------------------------------|------------------------------------------------------------------------------|-----------|
| Ease to Use (EtU)       | Changing page features, search options, and access                          | The home icon is easy to use (EtU1)                                           | [12]      |
|                         |                                                                             | Start, Stop, Pause, Previous, Next are large and easy to use (EtU2)          | [12]      |
|                         |                                                                             | Reading mode (Narration and non-narration) button is available (EtU3)       | [12]      |
| Multimedia (M)          | Features text, graphics, fonts, animation, and audio                       | Large and appropriate font (M1)                                             | [14]      |
|                         |                                                                             | Exciting animations and appropriate the content (M2)                        | [15]      |
|                         |                                                                             | Music effects do not interfere with the content, and it can motivate (M3)   | [16]      |
| Interaction (I)         | Hyperlink or button icon that triggers an event or action                   | Text interactions support word introduction, vocabulary, and understanding (I1) | [18]      |
|                         |                                                                             | Educational content interactions (I2)                                        | [18]      |
|                         |                                                                             | Effective Supplemental games or quizzes (I3)                                | [19]      |

| Linguistic Scale        | Triangular Fuzzy Scale | Triangular Fuzzy reciprocal Scale |
|-------------------------|------------------------|----------------------------------|
| Just Equal              | (1,1,1)                | (1,1,1)                          |
| Equally Important       | (1/2,1,3/2)            | (2/3,1,2)                        |
| Weakly Important        | (1/3,2/2)              | (1/2,2/1,3)                      |
| Strongly More Important | (3/2,2,5/2)            | (2/5,1/2,2/3)                    |
| Very strong more important | (2,5/2,3)          | (1/3,2/5/1,2)                    |
| Absolutely more important | (5/2,3,7/2)         | (2/7,1/3,2/5)                    |

| Table 3. Results of TFN on digital book assessment criteria. |
|---------------------------------------------------------------|
| EtU | M   | I  |
|-----|-----|----|
| EtU | (1,1,1) | (1/2,1,3/2) | (1/3,2/2) |
| M   | (2/3,1,2) | (1,1,1) ) | (1/2,1,3/2) |
| I   | (1/2,2/3,1) | (2/3,1,2) | (1,1,1) |

| Table 4. Results of TFN of sub Criteria ease to use digital books. |
|---------------------------------------------------------------|
| EtU 1 | EtU 2 | EtU 3 |
|-------|-------|-------|
| EtU 1 | (1,1,1) | (1,3/2,1) | (3/2,2,5/2) |
| EtU 2 | (1/2,2/3,1) | (1,1,1) | (1,3/2,2) |
| EtU 3 | (2/5,1/2,2/3) | (1/2,2/3,1) | (1,1,1) |

| Table 5. Results of TFN of sub-criteria Multimedia digital books. |
|---------------------------------------------------------------|
| M1 | M2 | M3 |
|----|----|----|
| M1 | (1,1,1) | (3/2,2,5/2) | (2/3,1,2) |
| M2 | (2,5/1,2,2/3) | (1,1,1) | (1/2,2/3,1) |
| M3 | (1/2,1,3/2) | (1,3/2,2) | (1,1,1) |

| Table 6. Results of TFN of digital book sub-criteria Interaction. |
|---------------------------------------------------------------|
| I1 | I2 | I3 |
|----|----|----|
| I1 | (1,1,1) | (1,2,2/3,1) | (2/3,1,2) |
| I2 | (1,3/2,2) | (1,1,1) | (3/2,2,5/2) |
| I3 | (1/2,1,3/2) | (2/5,1/2,2/3) | (1,1,1) |

3. Results and discussion
The evaluation results of digital book criteria and sub-criteria are presented in Table 7. It showed that the weight of importance level ease to use, Multimedia, and Interaction are 0.370, 0.330, and 0.300,
respectively. These results indicate that the ease to use criterion is the most critical criterion in evaluating a digital book. The criteria on the second and third-order are multimedia and Interaction criteria. These results are by research conducted by Roskos, et al. [11].

Furthermore, in the sub-criteria, the Home icon is easy to use (EtU 1) has the highest level of importance than others. It had a global weight of 0.206571. The second and third consecutive criteria are Educational content interactions (I2) and large and appropriate fonts (M1). This research implies that the selection of the right criteria can be a reference in the development of digital books.

| Criteria | Weight of Importance | Sub-criteria | Local Weight | Global Weight |
|----------|----------------------|--------------|--------------|---------------|
| Ease to Use (EtU) | 0.370 | Home icon is easy to use (EtU1) | 0.5583 | 0.206571 |
| | | Start, Stop, Pause, Previous are large and easy to use (EtU2) | 0.3446 | 0.127502 |
| | | Reading mode (Narration and non-narration) button is available (EtU3) | 0.0971 | 0.035927 |
| Multimedia (M) | 0.330 | Large and appropriate font (M1) | 0.4504 | 0.148632 |
| | | Exciting animations and appropriate the content (M2) | 0.1580 | 0.05214 |
| | | Music effects do not interfere with the content, and it can motivate (M3) | 0.3916 | 0.129228 |
| Interaction (I) | 0.300 | Text interactions support word introduction, vocabulary and understanding (I1) | 0.2886 | 0.08658 |
| | | Educational content interactions (I2) | 0.5055 | 0.15165 |
| | | Effective Supplemental games or quizzes (I3) | 0.2059 | 0.06177 |

4. Conclusion
This study aimed to evaluate the criteria for an excellent digital book using a fuzzy analytical hierarchy process. A case study was conducted on the evaluation of digital books in elementary school. Evaluation criteria used were easy to use, multimedia, interaction. The evaluation results of digital book criteria showed that easy criteria have the highest importance. Furthermore, multimedia and interaction criteria have second and third-order level importance weights. This research implies that the selection of the right criteria can be a reference in the development of digital books. Future research is necessary to explore more in-depth criteria and sub-criteria in digital book evaluations.

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