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Analysis of Digital Materials Designed in GeoGebra Materials Web Interface on Fraction Concept[1]

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Abstract: This research aims to examine the digital materials designed on the concept of a fraction on the GeoGebra.org/materials web interface (in Turkish), using rubrics in the context of educational features, visual design, and usability. In this research, which was carried out using the document analysis technique, 45 digital materials that already exist (as of 01/10/2021) on the concept of a fraction on the GeoGebra.org materials platform were evaluated. In the research findings, it was determined that the materials designed for the concept of fractions focused on equivalent fractions, multiplication in fractions, abbreviation, comparison, and addition/subtraction in simple fractions. In addition, it has been determined that the designed materials are materials with the same properties, which are generally prepared by being influenced by each other. It has been determined that the designed materials were insufficient to clearly state the learning outcomes, but they were partially sufficient in terms of other educational features. In addition, it was seen that the designed materials were insufficient in terms of being clear on how to use the material and providing clear instructions at first glance. However, it was determined that they were sufficient in terms of the consistent placement of the basic elements and the error-free operation of the material.
Keywords: *Geogebra.org, Digital Material, Fractions.*

1. INTRODUCTION

Regarding the fraction concept in the mathematics curriculum, it is known that students at every grade experience difficulty in the learning process (Bruce, & Ross, 2009; Gould, Outhred, & Mitchelmore, 2006; Lee, & Boyadzhiev, 2013; Olkun, & Toluk-Uçar, 2014; Tian, & Siegler, 2017). It is thought that these difficulties arise from the structure and teaching of fractions (Hansen, 2014; Moss, & Case, 1999). Many studies indicate the problems students face in learning fractions, especially when fraction operations are not associated with concrete experiences (Haser, & Ubuz, 2001; Keijzer, & Terwel, 2003; Orhun, 2007; Siegler, & Pyke,

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2013; Torbeyns, etc., 2014; Uz, 2018). Both the National Council of Teachers of Mathematics [NCTM] (2006) mathematics standards and mathematics education research agree that understanding fractions is an important element of mathematics learning. For example, the Curriculum Focus Points published by NCTM (2006) state that in Grade 3, students should:

> *"Develop an understanding of the meanings and uses of fractions to represent parts of a whole, parts of a set, or points or distances on a number line; understand that the size of a fractional part is relative to the size of the whole; use fractions to represent numbers that are equal to, less than, or greater than; solve problems that involve comparing and ordering fractions by using models, benchmark fractions, or common numerators or denominators; understand and use models, including the number line, to identify equivalent fractions."*

Orhun (2007) stated that students had difficulties in expressing fractions visually and in four operations in fractions. Uz (2018) stated that students find the concept of fractions abstract and therefore they have difficulties in learning. Bruce and Ross (2009) stated that they had learning difficulties due to the inability to make sense of the meronymy of fractions and the difficulty of representation.

It is known that teaching materials can respond to developmental needs and make the teaching process more meaningful by taking into account individual differences (Demirel, & Yağcı, 2007; Şahin, & Yıldırım, 2004; Prastowo, 2011; Velicova, 2011). The digital teaching materials included in these materials can be considered as teaching materials designed through digital media (Rogers, Sharp, & Preece, 2011; Stepherd, 2012). It is thought that these materials will help the development of knowledge construction, discovery, and active learning process in the classroom teaching process (Henderson, & Romeo, 2015; Setiyani, Ferdianto, & Fauji, 2020; Wright, 2015). In this context, in the mathematics learning-teaching process, abstract concepts will be presented by embodying them with visual representations through GeoGebra software. According to Kutluca and Zengin (2011), the relationships between mathematical concepts will be better understood by students with the increase of visualization thanks to GeoGebra software. For this, it is important to design well-structured digital teaching materials. In addition, subjecting digital materials designed for teaching purposes to certain evaluation criteria and determining their qualifications will be beneficial in terms of reaching the learning outcomes at the desired level (Arslan, 2016; Ateş, Çerçi, & Derman, 2015; Erensayın, & Güler, 2017; Kazu, & Yavuzalp, 2008). On the GeoGebra.org platform, there are already many digital materials designed with GeoGebra software for different learning domains (GeoGebra.org, 2021). Figure 1 shows a section from the GeoGebra.org platform.

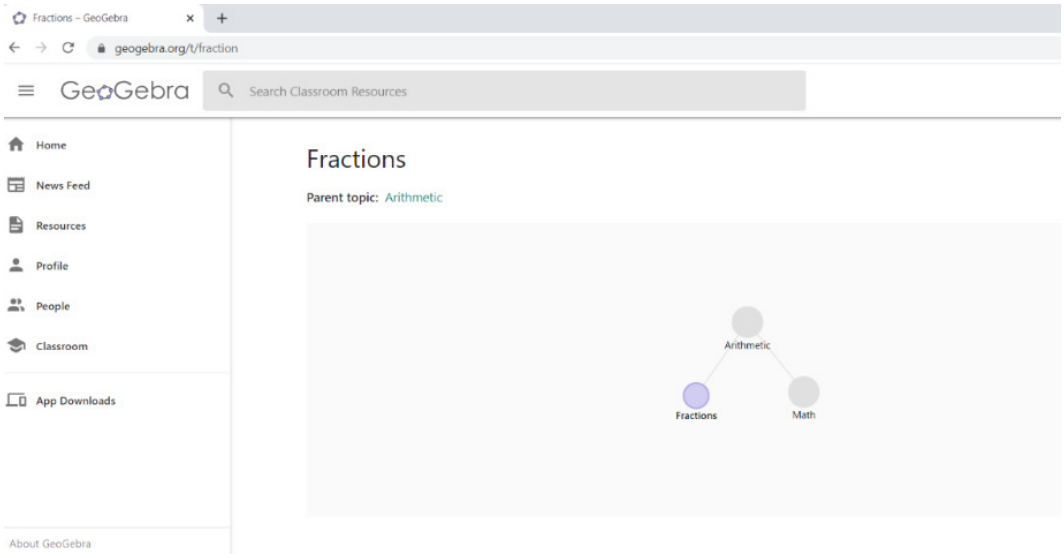

Figure 1. *An Excerpt from the GeoGebra.org Platform (GeoGebra.org, 2021)*

Many digital materials on the GeoGebra.org web interface are designed by volunteer researchers (teachers, students, academics, etc.) and can be shared with anyone, free of charge, on the platform. These digital materials are classified according to sub-disciplines and learning areas of mathematics, and their contents are updated by adding new digital materials every day. However, it is seen that these designed digital materials were not subjected to any evaluation criteria during the process of adding them to the GeoGebra.org web interface. This research aims to examine the digital materials designed on the concept of a fraction on the GeoGebra.org/materials web interface (in Turkish), using rubrics in the context of educational features, visual design, and usability. For this purpose, answers to the following questions were sought:

1- How is the distribution of digital materials designed on the concept of a fraction on the GeoGebra.org/Materials web interface?
2- What is the level of the digital materials designed on the concept of a fraction on the GeoGebra.org/Materials web interface in terms of educational features, visual design, and usability?

2. METHODOLOGY

3.1. Model of the Research

The data of this research was obtained by using the document analysis technique, one of the qualitative research methods. Document analysis is a research method used to analyze the content of written documents meticulously and systematically (Wach, & Ward, 2013). Document analysis is a systematic method used to examine and evaluate all documents, both printed and electronic materials. Like other methods used in qualitative research, document analysis requires the examination and interpretation of data to make sense of it, to form an understanding of the relevant subject, and to develop empirical knowledge (Corbin, & Strauss,

2008). Document analysis includes the analysis of written materials containing information about the case or cases that are aimed to be investigated (Yıldırım, & Şimşek, 2005). For this, 45 digital materials that are currently (as of 01.10.2021) on the concept of a fraction on the GeoGebra.org materials web platform were evaluated. Among these 45 materials, it was determined that 20 materials had similar content with each other. Only two of these 20 materials were evaluated. Therefore, within the scope of the research, 27 materials were directly included in the evaluation. While presenting the visuals of the evaluated materials, an English language translation was made.

3.2. Data Collection Tools

To examine the digital materials included in the evaluation, the Digital Material Evaluation Rubric [DMER] was developed by the researchers within the scope of the educational software evaluation criteria existing in the literature (Ateş, 2011; Erensayın, & Güler, 2017; Şahin, & Yıldırım, 2004) and research problems. DMER consists of two dimensions: educational features, visual design, and usability. The educational features dimension consists of six proficiency indicators, and the visual design and usability dimension consist of four proficiency indicators. The adequacy indicators of the dimension of the educational feature of DMER are given below:

1. Are learning outcomes clearly stated?
2. Is the content appropriate for learning outcomes?
3. Does the content reflect the subject matter engagingly and effectively?
4. Does it support the teaching of the course subjects?
5. Does it support an effective interaction with students?
6. Does it support higher-level thinking skills?

The adequacy indicators of the visual design and usability dimension are as follows:

1. At first glance, is it clear how to use digital material?
2. Does the splash screen offer clear directions?
3. Are essential elements (text, navigation keys, etc.) placed consistently?
4. Does the operation of digital material have errors?

A pilot study was conducted on 10 randomly selected digital materials on fractions on the Geobegra.org web platform to test the construct validity and reliability of the DMER and to identify potential shortcomings. In addition, the opinions of two faculty members who are experts in the fields of computer and mathematics education were consulted to conduct an expert analysis. By analyzing the results of the pilot study with the expert review and researchers, it was concluded that the indicators discussed in two dimensions were sufficient for the research.

3.3. Analysis of Data

The analysis of the research data was carried out in three stages as reviewing the analysis (superficial review), reading (detailed review), and interpretation adopted by Corbin & Strauss (2008). First, the performance levels of DMER were determined as “insufficient”, “partially

sufficient" and "sufficient" from lowest to highest. In this case, scoring values of one (1) for insufficient, two (2) for partially sufficient, and three (3) for sufficient were used. In addition, for the rubric average score values, classifications were made as below or above the determined performance levels, and the average scores were referred to in parentheses. The average scores of each group based on sub-dimensions were calculated with numerical data. After the digitization of the data, the average of the item scores was calculated and the sub-dimension score of each group was formed. In the analysis of quantitative data collected through DMER, descriptive analysis techniques were used by making use of Jamovi (The jamovi project, 2020) software. The data obtained were interpreted based on the tables. Within the scope of the research, it was tried to increase the credibility of the data by making use of the visuals.

During the current study, ethical principles oversight was adopted. For this reason, the names of the persons or organizations that prepared the material are hidden, especially when the figures are presented. The principles of scientific research and publication ethics were followed in the process of establishing the theoretical framework of the study, collecting data, analyzing and interpreting data. References to other publications in the study were made in accordance with scientific rules and they were presented in the bibliography following the APA style.

3. FINDINGS

In line with the first problem of the research, it has been determined that the materials designed on the concept of a fraction on the GeoGebra.org/Materials web platform focus on equivalent fractions, multiplication in fractions, abbreviation, comparison, addition/subtraction in simple fractions, modelling and other. Table 1 shows the distribution of materials designed on the concept of fractions by subject.

Table 1. *Distribution of Materials on The Concept of Fractions by Subject on The Geogebra.Org/Materials Web Platform*

Subject	%	*f*
Equivalent Fractions	32	14
Multiplication in Fractions	4	2
Abbreviation	4	2
Comparison	6	3
Addition/subtraction	8	4
Modelling	21	9
Other	25	11
Total	**100**	**45**

In addition to the findings in Table 1, it has been determined that the designed materials are generally prepared by being influenced by each other, with similar content, that is, they are copies of each other. Figure 2 shows a section on the Geogebra.org page that demonstrates this finding.

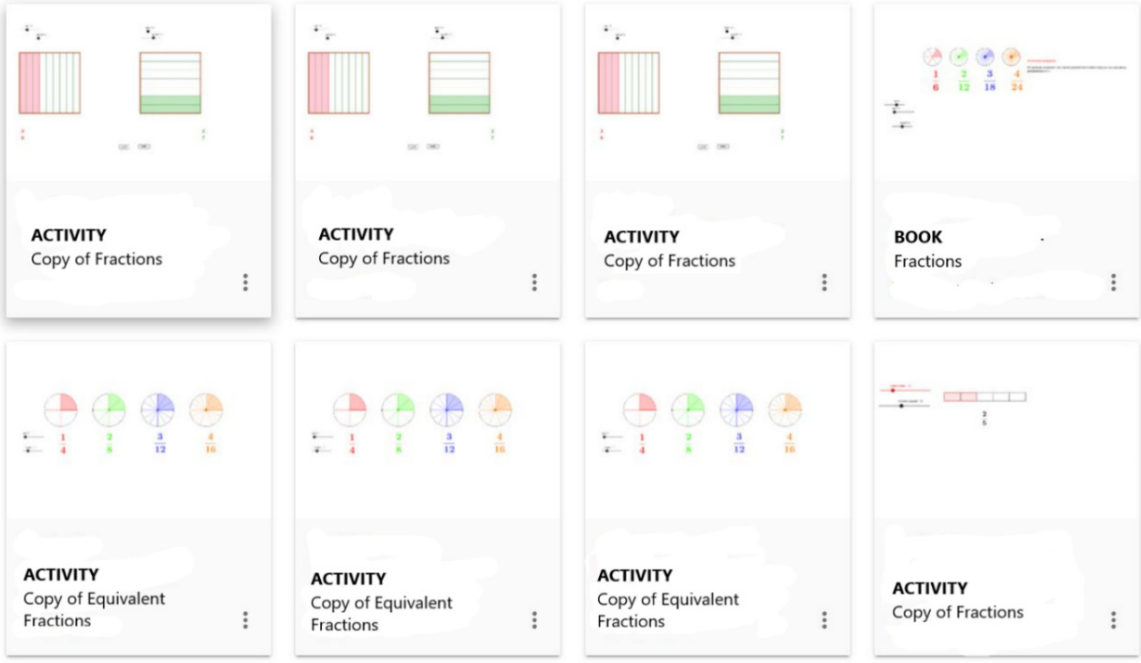

Figure 2. *Materials with Similar Content*

When Figure 2 is examined, it is seen that the materials on the platform are loaded more than once in a way that is repeated, that is, as copies of each other. The fact that 22 materials out of 45 digital materials were excluded from the scope of the study because they have the same characteristics, confirms this finding. In addition, among the materials designed on the concept of a fraction on the GeoGebra.org/Materials web platform, no materials designed by considering individual differences have been identified. In other words, there is no classification of digital materials as basic-intermediate-advanced level. Again, no information was found that any of the digital materials designed on the GeoGebra.org/Materials web platform were created according to the criteria of digital material design.

In line with the second problem of the research, the following findings were reached. When we examine the rubric dimensions in the context of the educational features of DMER, it has been determined that the designed materials are insufficient to clearly state the learning outcomes, but they are partially sufficient in the context of other educational features. Table 2 presents the results of this finding.

Table 2. *Rubric Performance Levels in The Context of Educational Features*

	Insufficient		**Partially Sufficient**		**Sufficient**	
	%	***f***	***%***	***f***	***%***	***f***
Are learning outcomes clearly stated?	48	13	22	6	30	8
Is the content appropriate for learning outcomes?	15	4	41	11	44	12
Does the content reflect the subject matter engagingly and effectively?	33	9	26	7	41	11
Does it support the teaching of the course subjects?	18	5	22	6	60	16
Does it support an effective interaction with students?	37	10	22	6	41	11
Does it support higher-level thinking skills?	33	9	33	9	33	9

In the context of rubric sub-dimensions, when we examine the performance scores for all levels separately, the following results are obtained: It has been determined that the designed materials are below the partially sufficient level in terms of clearly stating the learning outcomes ($\bar{X}_{Learning\ outcomes}$=1,81). It has been determined that the prepared content is above the partially sufficient level in terms of its suitability for the learning outcomes ($\bar{X}_{Suitability}$=2,30). In the context of other educational features, it was determined that the designed materials were partially sufficient. That is, the content's ability to reflect the subject in an interesting, lively, and effective way was determined as $\bar{X}$=2,07 and the content's ability to provide an effective interaction with students was determined as $\bar{X}$=2,04. In Figure 3 positive and negative visuals related to these results are given.

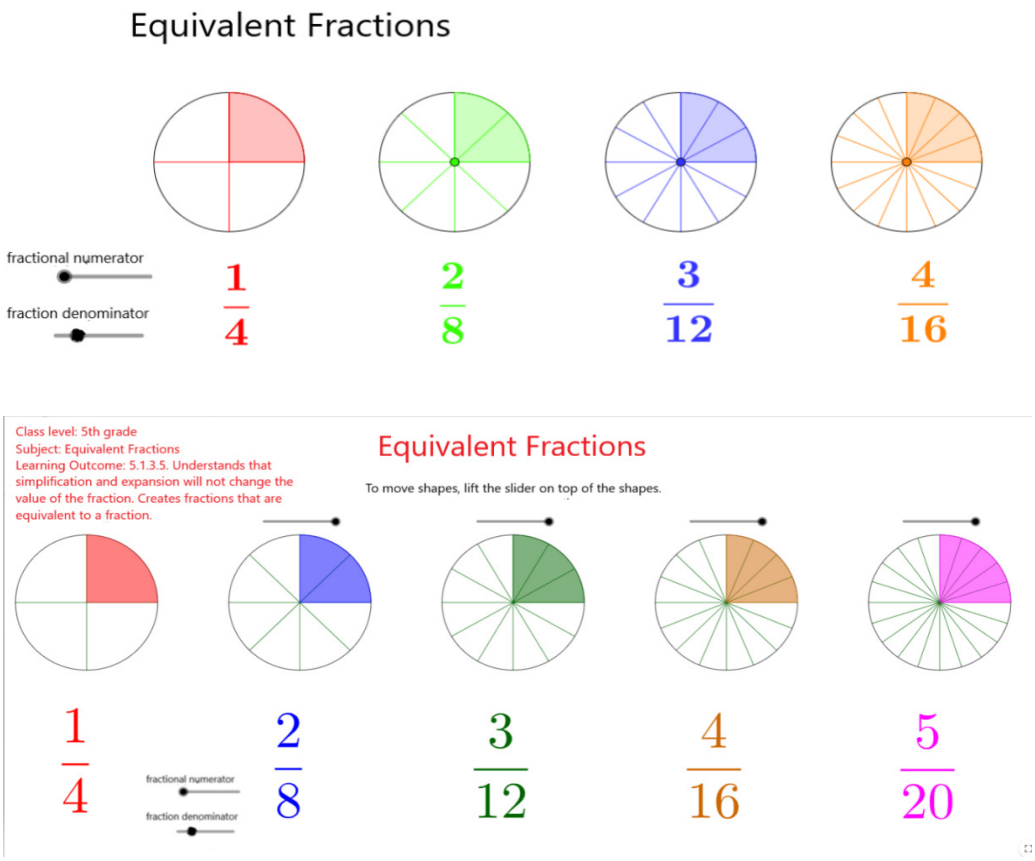

Figure 3. *Examples of Images on The Geogebra Web Platform for Rubric Sub-Dimensions*

Figure 3 shows two different digital materials. When Figure 3 is examined, it is seen that the above image does not include the learning outcomes and the content is not capable of revealing rich situations. However, in the image below, we see that the learning outcomes are stated and the content is supported in a way that reveals rich situations.

In the context of visual design and usability features of DMER, when we examine the rubric dimensions, it is seen that the designed materials are insufficient in terms of being clear on how to use the material and providing an understandable direction at first glance. However, it was determined that they were sufficient in terms of the consistent placement of the basic elements and the error-free operation of the material. In Table 3, the results of this finding are given.

Table 3. *Rubric Performance Levels in Terms of Visual Features and Usability*

	Insufficient		**Partially Sufficient**		**Sufficient**	
	%	***f***	***%***	***f***	***%***	***f***
At first glance, is it clear how to use digital material?	70	19	18	5	12	3
Does the splash screen offer clear directions?	60	16	26	7	14	4
Are essential elements (text, navigation keys, etc.) placed consistently?	8	2	22	6	70	19
Does the operation of digital material error-free?	3	1	8	2	89	24

In the context of rubric sub-dimensions, the following results were obtained when we examined the performance scores for all levels separately: At first glance, it was seen that the designed materials were below the partially sufficient level in terms of being clear about how the material would be used ($\bar{X}_{Being\ clear}$=1,41) and providing an understandable orientation ($\bar{X}_{Redirection}$=1,56). However, it was determined that they were above the partially sufficient level in terms of average rubric performance scores in the context of consistent placement of the basic items ($\bar{X}_{Consistent\ placement}$=2,63) and error-free operation of the material ($\bar{X}_{Error\text{-}free\ operation}$=2,81). In Figure 4 positive and negative visuals related to these results are given.

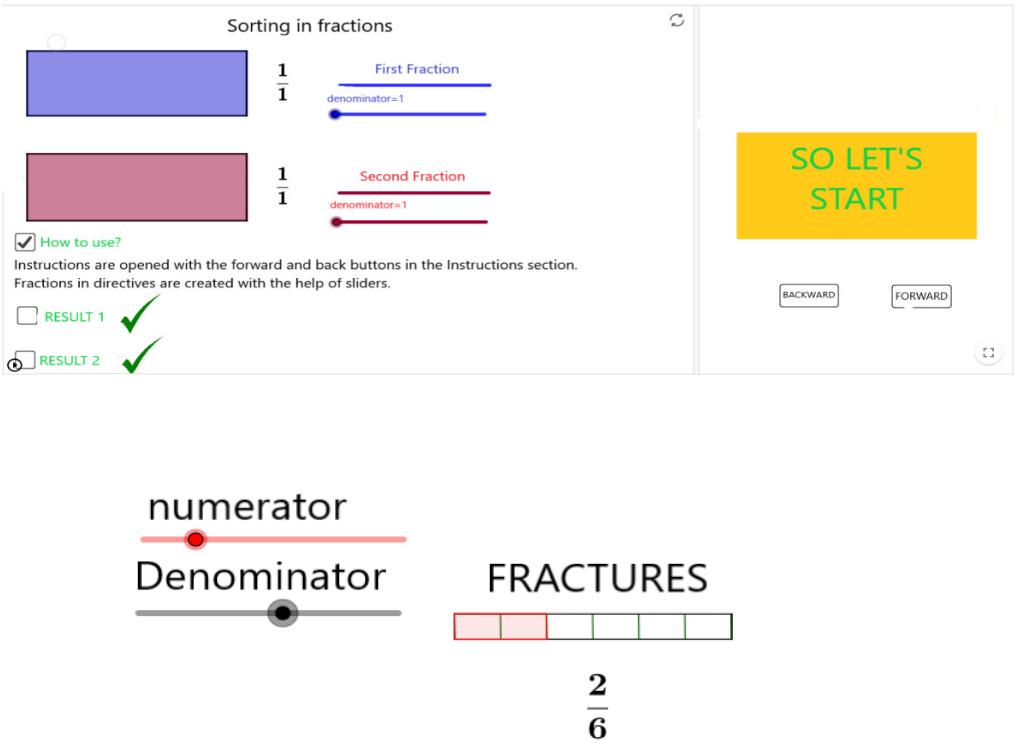

Figure 4. *Examples of Images on the GeoGebra Web Platform for Rubric Sub-dimensions*

Figure 4 shows two different digital materials. When Figure 4 is examined, it is seen that the material above is at a sufficient level in terms of presenting an understandable instruction, consistent placement of the basic elements, and error-free operation. However, when we look at the material below in Figure 4, there is no instruction or clear direction. It is also seen that the basic elements cannot be placed consistently with each other.

4. RESULTS AND DISCUSSION

As a result of the research, it can be said that uploading similar materials to the GeoGebra.org web platform one after the other will create confusion for those who want to take advantage of the platform. It can be stated that this situation will take a time-consuming and complex structure for people who want to benefit from the material, and it will reduce the number of people who want to benefit from the platform. In addition to this result, it is seen that the materials prepared on the concept of a fraction on the GeoGebra.org/Materials web platform are insufficient/partially sufficient in many sub-dimensions in the context of the material evaluation rubric. This result can be interpreted as an indication that digital materials did not pass any evaluation criteria while uploading to the system or during the design phase. In this context, it is thought that the contribution of digital materials that have not passed any evaluation criteria to the teaching process will be low and will be insufficient in terms of reaching the desired learning outcomes. As a matter of fact, this result is similar to the studies in the literature (Ateş, Çerçi, & Derman, 2015; Erensayın, & Güler, 2017; Kazu, & Yavuzalp, 2008; Prastowo, 2011; Setiyani, Ferdianto, & Fauji, 2020). Again, as a result of the research, materials that students can use according to their level were not found by testing students' prior

knowledge and making basic-intermediate-advanced classifications according to the results. Therefore, it is thought that this situation will create confusion in the use of materials in terms of teachers and students. It was observed in the studies conducted that teachers focused on this result and stated that it was necessary to classify them as basic-intermediate-advanced (Arslan, 2016; Erensayın, & Güler, 2017).

In the research findings, it has been determined that the designed digital materials have deficiencies in terms of educational features, visual design, and usability. When we examine these shortcomings, it is seen that the majority of the materials are insufficient to clearly state the learning outcomes. In other words, it can be said that in the designed materials, there is no information about the teaching of which concept is related to which grade level or fractions sub-learning domain. This situation is thought to be a challenge especially for teachers who have just started their profession. In addition to this result, it was determined that the content in the designed materials was partially above the sufficient level in terms of being suitable for the learning outcomes. As a matter of fact, in the study conducted by Erensayın and Güler (2017) with teachers, it is emphasized that the criterion of the learning outcomes in the materials should be suitable for the level of the student. However, in another study conducted by Arslan (2016), it was found that the materials published on Education Information Network [EIN][ii] were not suitable for the level of students within the scope of mathematics concepts. This result is in contradiction with the results of this study, which was conducted specifically on the concept of fractions. From this point of view, we can say that the materials designed on the concept of fraction in the GeoGebra.org resources platform are more adequate in terms of being suitable for the level of the student compared to the materials on the EIN platform. In the context of visual features and usability, which are among the dimensions of the rubric, it has been determined that the materials have deficiencies, especially in terms of usability at first glance and providing guidance. It is thought that this situation will create difficulties for students who want to benefit from the designed materials individually. Therefore, it can be said that the materials need to be developed in terms of interacting with the user.

5. RECOMMENDATIONS

As a result of the research, the following recommendations were made:

It is recommended that the designed materials pass through concrete evaluation criteria before they are uploaded to the GeoGebra/Materials web platform. In addition, indicators such as blue clicks, etc. can be added to show that materials that meet certain criteria are approved (for example, similar to approved accounts in social media environments), and the option to search only among these materials can be offered. In addition, target achievements can be expressed more clearly. The quality and quantity of instructions and directions can be improved in terms of the usability of the materials. Loading of repetitive materials on the platform can be prevented.

[ii] Turkey's digital education platform, EIN, is a platform established to communicate between educators and teachers and to provide materials that they can use throughout their education life (EIN, 2021).

6. ABOUT THE AUTHORS

Nurullah YAZICI: He is currently an assistant professor at the Department of Primary Mathematics Education. His research interests include teaching and learning of mathematics, technology integration in mathematics education, SOLO Taxonomy, misconceptions.

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