Games for Learning Fractions: Digital or Physical Games?

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Abstract. It's been years to years fractions have been known as one of the most difficult topics in mathematics to be learned. In some cases, this situation even can lead to others learning problems such as students' anxiety and loss of motivation for learning mathematics. Failure in understanding the basic concept of fractions will hinder the students' learning of further algebraic concepts. Games become one of the options that can be chosen for solving this problem. There are various designs of the games either digital or physical games which have been released and played to teach the fraction concepts. Nowadays as digital games become more and more accessible for students, the case of games addiction is increasing significantly. This situation has affected some schools and teachers to limit the use of digital games for classroom teaching. Teachers tend to use physical games instead digital games in their classrooms. The fact, besides the negative impact of digital games, at the same time this situation indicate that there is an opportunity to use digital games as a learning tool for teaching fraction concept. This paper aims to analyze the use of games for teaching fractions through a literature review. A bibliographic research design using PRISMA framework will be carried out. Data resources were referred to Scopus data based from the year of 2017 until 2022. Only journal paper and conference proceeding were included in the data set. The result of this study will be beneficial for developing a game design for teaching fractions either digital or physical.

Keywords: Fractions, digital game, physical, PRISMA, Vos Viewer

1 Introduction

Topic of fraction has been known as one of the most challenging topic in mathematics for many students. At the same time, fractions is one of the fundamental concepts which can be found in many daily activities, in addition concept of fractions is a gate to acquiring more advanced mathematical skills [1] and a gateway for the STEM profession [2]. Unfortunately, many studies show that the students are struggling to understand the concept of fractions with various reason since long time ago, so they just remember the rules as the solution of their problem without understanding why the rules are

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worked[3]. One of the reason why fractions is challenging for many of the students is because fractions has various meaning, it can be a rational number, it can be a division operation, it can be representation of part of whole, it also related to the concept of proportion [4, 5, 6, 7].

Understanding the difficulties of learning fraction is essential because the obstacle of learning fraction can lead to anxiety problem and will affect the students' attitude and engagement in learning mathematics and Science [7].Referred to the situation, researcher, teacher and mathematics educator have been tried to solve the problem through intensive researches and experiments. Based on the study of Emilie et al there are some strategies have been used by teachers to teach fraction. Those strategies can be categorized into four categories: (1) Engagement Strategy; (2) Teaching Style; (3) Classroom Material, and (4) Promoting Thinking and Reflection [8]. As the study conducted in the time while game in education is not popular yet, so that the link between the strategies and topic of games seems invisible. On the contrary, the recent trend on education research involving the topic of games, how games can be used as a tool in delivering various lesson including mathematics.

A bibliographic study conducted by [9] shows that games can be very effective to increase not only students' motivations but also students' engagements. In addition, educational games provide an alternatives to make the learning more fun and full of joy for students as well as teachers. At the same time it also has potential to provide a high-quality learning material which is inexpensive, flexible, portable, and relaxing both for teacher as well as students. In relation with the complicated concept of fraction, games can be one of the alternative to be explored further.

Games in teaching mathematics actually not really a brand new idea because since the era Dienes, physical games became an essential method for teaching some basic concept in mathematics[10]. The massive advancement on technology has been encouraged the emergence of digital game for teaching various concept in mathematics. While probably not all mathematics teachers familiar with games for teaching mathematics, the existence of both digital and physical games need to be promoted to mathematics teacher as one of the strategy for helping their students in understanding the concept of fractions.

This study wanted to know how teachers perceived games for teaching fractions, and their preference and experiences between digital and physical games to be used in their mathematics classroom.

2 Literature review

2.1 Concept of Fractions

Fractions can be defined as a non negative rational number that be write in form of $\frac{a}{b}$, a, and b are positive integers and b cannot be zero. This definition is accepted I mathematics, but it will be more challenging when the definition is used to teach fractions into students in elementary schools. Based on most curriculum, concept of fraction usually delivered before the concept rational number and after students learn the concept

of natural and integer number or at least in paralel with them. This become one of the problematic issues in the mathematics curriculum design [11]. The main causes of students' difficulties in understanding the concept of fractions the interference with students' prior knowledge on the concept of natural number [12]. This condition known as 'whole number bias' leads to students' misconception because they prior knowledge of concept number need to be changed, for example students become confuse when they multiply two fractions, the result will be smaller from its original number. In this case students face a contradiction situation. In order to overcome the bias between natural number and fractions, therefore students need to reconstruct and consolidate their knowledge of numbers.

As fractions has multifaceted meaning, the process of constructing a clear definition of fractions and number becomes more challenging. Based on previous studies, in order to develop a full understanding of fractions, students need to construct five distinguished meaning of fractions [13, 14, 15] :

1. The 'part-whole' meaning of fractions refers to a continuous quantity when a set or an object divided into parts of equal size [15, 6]. A fraction is viewed as a comparison between the selected number of equal sized parts and the total number of equal sized parts. This is one of the most familiar meaning of fractions used by teachers to introduce concept of fraction. A typical example the use of part-whole meaning of fractions is when teacher giving a rectangle or circle represent 1/4 of a figure, then teacher asked students to complete the whole figure.
2. The 'ratio' meaning of fractions refers to the notion of a comparison between two quantities and as such, it is considered to be a comparative index rather than a number[6]. The example of this situation was illustrate very well in the process of making two glass of orange juices with different proportion of water and juices. The orange juice experiment has been widely used to measure students' understanding of this meaning of fractions [16].
3. The 'operator' meaning of fractions refers to the application of a function to a number, an object, or a set. In case the nominator is bigger than the denominator, it is an operation to stretch an object, a number, or a set; in case the denominator is bigger than the nominator, it is regarded as an operation to shrink. An example of fractions as the operator can be represent by case when students are asked to measure 2/3 part of a bar with specific length ℓ.
4. The 'quotient' meaning of fractions refers to the result of a division. It is contrary to the part-whole meaning when two different measure units are considered. For example, there are five bar of chocolates will be equally divided among four friends. How much does anyone get?
5. The 'measure' meaning of fractions taken place when fractions are seen as numbers that can be ordered on a number line. As such, this meaning is associated with two intertwined notions [13]. The number-notion refers to the quantitative aspect of fractions (how big is the fraction) while the interval-notion concerns the measure assigned to an interval. Within the first notion, is seen as 0.75 while in the second notion, corresponds to a distance of 3 ¼-units from a given point

[6]. The number line is recognized as a suitable tool to assess students' interpretation of fractions as a measures.

2.2 Physical Games for Teaching Fractions

The connection between game and mathematics is not a new idea. It can be traced from the history when Archimedes invented a mathematical game similar to tangrams or when card game SET became favorite for mathematicians. Game such as chess can be consider a game which provide continue and fruitful investigation. There is a natural affinity between mathematicians and games or puzzles. Games also can be used too investigate pattern, prompt conjecture, and promote the ownership of mathematics, so that it can be used to help students learning difficult mathematics concepts. While games have been more widely accepted and employed in mathematics classrooms at the elementary and middle school levels, they are a relatively untapped resource at the collegiate level[17].

2.3 Digital Games

One of the global pedagogical approaches required for 21st century learners is the use of digital games for education has been identified as [18]. Individuals in any age range can learn through digital games. Ultimately, it is more practical to use such games in kindergarten to grade 12 education (primary and secondary school) to increase students' levels of interest in difficult subject such as mathematics. An interactive gaming system uses advanced graphics and programming tools. Mathematics content can be gamified easily in the current digital era. Game designers and developers often collaborate with teachers and experts to construct good instructional games for teaching mathematics concepts. This type of pedagogical approach is known as digital game[19].

3 Research method

This is a preliminary study to develop a game for teaching fractions which would like to explore how teachers perceive games as a tool for teaching fraction and which games they prefer to be used in their classroom. There are two research questions driven the study: (1) how familiar teachers with games for learning fractions? and (2) based on literature reviews, which type of games need to be develop for teaching fractions? Intending to answer the questions, a survey during focus group discussion and a bibliographic studies carried out in this study.

3.1 Survey and Focus Group Discussion (FGD)

As the study wanted to collect data from mathematics teachers in Indonesia, a survey was started before a focus group discussion with topic "Teaching Fractions Through Games" was conducted in July 20th, 2022 in hybrid mode. The survey was conducted

to collect personal information about teachers participants who would like to join the FGD and 5 open questions:

1. Have you ever been used games for teaching fractions in your class?
2. Based on answer number 1, could you please write the argumentation why you used games or why you do not use game?
3. Does your students like learning through games in classroom?
4. Based on question number 3 if your answer is "yes" what kind of games they like it?
5. What are the obstacles in using games in your classroom?
6. Do you interested in using games for teaching fraction in your classroom?
7. Which type of games more suitable for your classroom digital or manual games?

The survey conveyed before the discussion was started using google form. The survey was conducted using convenience sampling, from total participants 167 participants there were 46 respondent who participated in survey. Data were analyzed using qualitative method, by clustering the topic of discussion and using descriptive statistic to find the percentage of teachers who familiar with games for teaching fractions and to discuss which type of games that most teachers are familiar with.

After collecting information from survey, the FGD conducted by inviting all the participants who participated in the survey. The FGD is one of the method that can be used for clarifying, extending, and challenging data collected through other method [20] so that in this study the FGD was conducted to clarify, extend, and challenge data from survey. The participants of the discussion consist of expert researcher on the topic of games from Linz University, Austria, lecturers and researchers from mathematics education department, faculty of teachers training and education, Sebelas Maret University, Indonesia, secondary school mathematics teachers, and elementary schools mathematics teachers from all around Indonesia. There were 25 offline participants on the location and 142 online participants in zoom.

Data during FGD were collected through video recording, transcribing notes, and from zoom chat box. During the FGD session all the questions from survey were confirmed to the audience in the discussion session, this is as one of the methods for doing data triangulation in qualitative research.

3.2 Bibliographic Analysis

In an effort to explore the research topic related to games and fraction, a bibliographic analysis was conducted as the third method on the study. Data were collected from Scopus database since 2017 until 2022 with three keywords, games, digital, and fractions. There were 188 papers resulted from the first step, then one paper was drop out because that is not an academic article. In the second step, 187 articles were analyzed manually from the title and abstract and resulted into 156 papers which are relevant to the keywords. Data analysis in this study was conducted manually using PRISMA, Mendeley and VosViewer applications.

4 Result

The survei consisted of five questions which explore the experiences of teachers in using games for teaching fractions and what kind of games they have already know and having the skills to use it in their classroom. Data from the survei shows that 52, 17% out of 46 participants teachers never use games for teaching fractions as illustrated in Figure 1.

Fig. 1. Percentage of participants teachers who have taught fractions using games

Even though 47, 83% of the respondents have newer tried to use games for teaching fractions but they have the knowledge of what kind of games that can be implemented in their classroom for helping students learn concept of fractions. Based on the data, three categories of games emerged they are: online games, offline games and role play games as shown in Figure 2 below:

Fig. 2. Venn Diagram of Survei result about the type of games

Referred to Figure 2, it can be seen that the most popular type of games is online games. As online games become more and more popular in line with the popularity of the internet, teachers become more familiar with type of digital time. Some digital games that they mentioned on the survey from 37 participants are: *Geogebra*, *Desmos*, *Quizizz*, *Kahoot*, and games from www.mathlearningcenter.org. while offline games emerged from the data are: board game such as card game, snake and ladder, and monopoly; puzzle,

and role play. There were 19,6% participants who were not familiar with any games at all.

Based on the result analysis, some obstacle faced by the teachers to use games in their mathematics instruction are can be categorized into three major themes: (1) knowledge about games both for teachers as well as students; (2) facilities and infrastructure of the schools and technology in general; (3) the skills in using games. Majority of the respondents said that they have limitation to the resources of the games and at the same time most of them said that their students having difficulties in understanding the rules of the games. Most of the teachers also gave information that they never got an information about how to use games as part of the curriculum for pre-service mathematics teachers in their college education. Most of the teachers mentioned that they got information about games dor teaching math from training program that they involved in.

Most of the respondents who have used digital games mentioned that one of most challenging problem in using digital games is bad internet connection and lack of facilities in their schools because their students did not have access to education technology such as computer or tablet. They also mention that using games in the classroom can lead to bad time management in teaching. It was very difficult to control the time while student and playing together during the lesson.

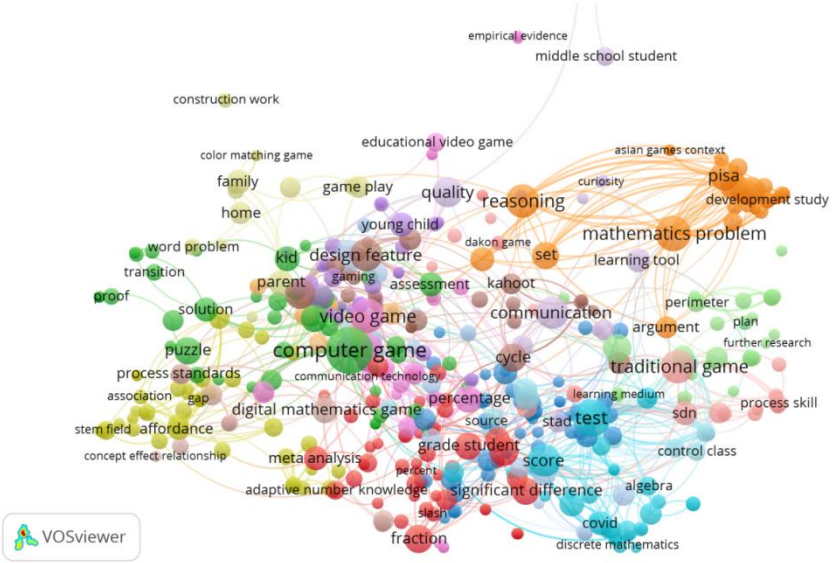

Fig. 3. Bibliometric analysis using Vos Viewer

Result from the bibliometric analysis using Vos Viewer identified that there are 21 cluster related to topic of games, fraction and digital terms that have been studied by researchers from year 2017 until 2022 based on Scopus database. There were 554 terms resulted from the abstracts and the title of papers in this study. Compare to traditional game, computer and video games is more popular among researchers.

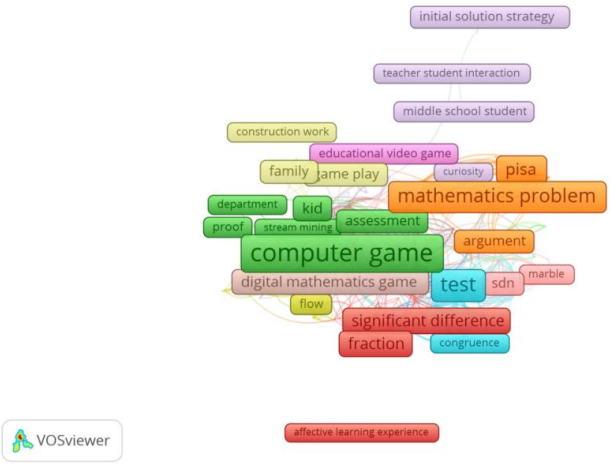

Fig. 4. Network Analysis Visualization from Vos Viewer

Five major topics related to games and fractions are computer game, test, mathematics problems, digital mathematics games and assessment. Other related notion with the games are related to game play and family as well as teaching strategi and interaction between teacher and students. So far the connection between games and fraction has nothing to do with topic of digital learning environment as a new filed in digital world.

5 Discussion

As the result from survey and FGD indicated that most of the respondents are still novice in using games for teaching fractions, both type of games digital or physical games become in the same position. This result is slightly difference with similar study conducted in Australia where most of primary teachers there use games at least ones in a week in mathematics classroom [21]. Some factors such as teachers having difficulties in finding the appropriate games or lacking of time to make games by themselves becomes majority argumentation why participants teachers never used physical game in their classroom while the limitation of education technology become common argumentation why they hesitate to use digital games in their mathematics classroom. The situation almost similar with a study conducted in Ontario, Canada which conclude that access to technology become major challenge for teachers to integrate game-based learning into their mathematics classroom [22]. On the other hand, most teachers who used games for teaching mathematics in their classroom were familiar with digital games but lack of resources related to games for teaching fractions. Based on these findings, introducing and providing physical games to primary and secondary teachers in Indonesia for teaching fractions can help teachers who would like to use physical games but having limitation to the resources of the mathematics games. In addition, for those teachers who familiar with digital games and fully equipped by digital technology can be assisted by providing a digital games for teaching fractions. This situation indicate that both types of games, digital and physical are necessary to be developed for supporting the use of games in mathematics classroom.

There some statements that indicate teachers' perception in using digital games for teaching fractions. They assumed that teaching fractions need to use physical manipulative rather than digital manipulative, so that they decided that almost impossible teaching fraction using digital games because fractions is very complicated concepts for students. The situation reflects that the teachers need assistance related to didactic and pedagogic aspects of teaching fraction using games, so empowering teachers with pedagogical competence for integrating games into their classroom is essential [23].

Another result related to the barrier that teachers faced in implementing game into their classroom are in line with study conducted by [24] that stated teachers need to acquire game literacy in order to teach meaningfully with games. This includes a balanced knowledge of four forms: (1) students' everyday knowledge including their knowledge of the game, (2) knowledge about the pedagogical practices in the school, (3) content knowledge, and (4) knowledge which is specific to the game (e.g. relevant game dynamics, genre, specialized knowledge embedded in the game). Furthermore, obstacles in using games for teaching mathematics not only related to the lack of up-to-date equipment, modern device, teachers professional and training program but also involved support from school administrative and a political will to reform the curriculum [25].

6 Conclusion

Based on this situation, providing teachers with various type of games both physical and digital is fundamental for promoting the use of games for teaching difficult topic such as fraction in mathematics. As for supporting the efforts, providing the resources will help teachers to gain more knowledge and skills to use the games in their classroom. The case of digital game will be related to concept of TPACK or Technological Pedagogical Content Knowledge of teachers. It can be part of digital literacy for teachers.

Related to topic of teaching fractions, as this concept consists of multifaceted notions so that games that design both in physical and digital will be beneficial for teachers. The study suggest to provide both physical and digital games for teaching fractions completed by a Teacher Professional Development Program (TPD) such Training program for mathematics teachers for providing them with CK, PCK, and TPACK related the use of games in teaching fractions concept.

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