Effectiveness of the Utilization of Educational Games Based on PhET Simulation to Improve Students' Understanding of Mathematical Concepts on Fraction Material

Lili Nur Indah Sari[*1], Annisatul Ahyar Batubara [2], Annisa Handayani Siregar [3]
[1,2,3]Tadris Matematika, Fakultas Tarbiyah dan Ilmu Keguruan,
UIN Syekh Ali Hasan Ahmad Addary Padangsidimpuan
lilinurindahsari@uinsyahada.ac.id[*1], annisatulahyar10@gmail.com[2],
annisahandayani164@gmail.com[3]

Abstract

The purpose of this study was to determine the effectiveness of the use of educational games based on PhET simulations in improving students' understanding of mathematical concepts at SMPN. Negeri 5 Padangsidimpuan. The method used in this research is Pre Experimental with One-Group Pretest-Posttest research design. The sample in this study were students of class VII-3 SMPN 5 Padangsidimpuan. Determination of students' understanding of mathematical concepts in this study using data instruments in the form of average pretest and posttest scores. The average student pretest score was 68.24% and the posttest had an average score of 84.62%. It can be concluded that the use of educational games based on Phet simulations can improve students' understanding of mathematical concepts in fraction material.

Keywords: *Education Game; Fraction; PhET.*

Abstrak

Tujuan dari penelitian ini adalah untuk mengetahui efektivitas pemanfaatan game edukasi berbasis simulasi PhET dalam meningkatkan pemahaman konsep matematika siswa di SMPN Negeri 5 Padangsidimpuan. Metode yang digunakan dalam penelitian ini adalah Pre Experimental dengan desain penelitian One-Group Pretest-Posttest. Sampel pada penelitian ini adalah siswa kelas VII-3 SMPN. 5 Padangsidimpuan. Penentuan pemahaman konsep matematis siswa pada penelitian ini menggunakan instrument data berupa rata-rata skor pretest dan posttest. Rata-rata nilai pretest siswa sebesar 68,24% dan posttest memiliki rata-rata nilai 84,62%. Dapat disimpulkan bahwa pemanfaatan game edukasi berbasis simulasi Phet dapat meningkatkan pemahaman konsep matematika siswa pada materi pecahan.

Kata Kunci: Game Pendidikan; Pecahan; PhET.

*Correspondence:
Email: lilinurindahsari@uinsyahada.ac.id

INTRODUCTION

Mathematics is one of the subjects that must be studied at all levels of education from elementary school to high school, even at the kindergarten level mathematics is studied informally. Mathematics can be defined as a science that explores the rational and logical nature of the cognitive processes involved in understanding ideas (Susilawati, Putri, and Nursangadah 2022). Mathematics is a scientific discipline that has an important role and influence on everyday life in the era of globalization. Not only that, mathematics has involvement in various aspects of human life such as in technology, economics, development, defense and other fields. A scientist named Roger Bacon said that "Matematics is the gate and key of scienses (Sirait et al. 2023). This is the reason why math is important to learn at every level of education.

Empirical facts state that mathematics is one of the subjects that most students dislike by assuming that math is a very difficult subject. One of the factors causing this is because the learning process is monotonous and boring so that students cannot understand the lesson meaningfully and perfectly (Rangkuti 2022). Mathematics learning will be more meaningful if students can find the concepts learned based on their own learning experience by taking an active role in the learning and using learning media that is in accordance with the material studied in order to analyze and solve problems in a more enjoyable and detailed manner.

This is a trigger for math teachers to continue to innovate in making changes in the children's learning environment. In accordance with the times, technology is needed to create math learning media that can develop students' ability to understand the lessons given. By providing challenges to students to solve math problems, so that they will generate motivation from within themselves to solve them (Arisandy, Marzal, and Maison 2021).

Learning media is a means or tool used by a teacher to assist the learning process. The use of learning media will help the interaction relationship between teachers and students, clarify information, provide variety, increase motivation and provide a good explanation related to the learning flow so that it can achieve

the expected learning outcomes (K et al. 2022). The use of learning media can also be presented in the display of educational games to students. A scary learning display can turn into fun learning and will strengthen students' memories because of interesting animations (Hadi et al. 2023).

The suitability of the approach and media used in learning with the material and characteristics of students can make the learning process of mathematics more enjoyable, so that students are more excited and feel happy in participating in the lesson. That way, the learning experience will provide a good understanding for students and improve student learning outcomes. Quoted from Almira Amir's journal (Amir 2021) In Permendiknas No. 22 of 2006, the purpose of learning mathematics is to understand mathematical concepts, explain the relationship between concepts and apply concepts or algorithms flexibly, accurately, efficiently and precisely in solving problems.

One of the efforts used to make it easier for students to understand lessons is using digital media such as PhET Corolado. PhET Corolado is an application created by the University of Corolado Boulder that offers interactive simulations containing elements, images, animations and can even respond or operate media as virtual aids (Masfaratna 2021). PhET simulation media is a website designed like a virtual laboratory in the form of interactive animations with a game-like display so that students learn through exploration. With an interesting simulation, it will make it easier for students to understand the material with a more concrete or real approach (Nursella 2024). When conducting experiments, students will be curious to use the platform and then change the parameters in the simulation to explore and improve understanding.

Some previous researchers have examined the use of PhET Simulations learning media in the field of education, including research conducted by Etty Dwi Lestari, et al. (Mayung et al. 2023) with the title Analysis of the Use of Digital Learning Media PhET Simulation to Improve Students' Concept Understanding. Based on the results of data collection conducted by means of interviews, observation and documentation, it shows that the use of PhET simulation website media can help students in providing an understanding of the

concept of one variable linear equation material so as to create an effective learning process (Uwambajimana et al. 2023). The use of educational games phET Colorado in fraction material aims to instill the basic concepts of fractions in a concrete and fun way. The learning process with this media will create an interactive and explorative learning experience to strengthen students' understanding of fraction material (Razali and Khalid 2021).

Based on the above background, the use of educational games based on PhET Colorado simulation is expected to be able to create effective learning and provide innovation in mathematics learning so as to improve students' mathematical understanding (Faizah et al. 2023).

The purpose of this study is to determine the effectiveness of using educational games based on PhET simulations in improving students' understanding of mathematical concepts on fraction materials. In detail, this research serves as a reference for teachers in choosing and applying interactive learning media that is effective in improving students' understanding of fraction material so that it contributes to the development of mathematics learning, especially technology-based mathematics.

RESEARCH METHODS

This research was conducted with quantitative research. The method used is Pre Experimental with the research design One - Group Pretest-Posttest Design. Where in this research design there is one group that will be given an initial test in the form of a pretest to determine the initial ability of students then given treatment (treatment) and then observed the results before being given treatment and after being given treatment (treatment is as an independent variable and results are as dependent variables) (Adhi Kusumastuti, Ahmad Mustamil khoiron, Taofan Ali Achmadi 2020). This research was conducted at SMPN 5 Padangsidimpuan with a research sample of VII-3 grade students of SMPN 5 Padangsidimpuan. The sampling process with Purposive Sampling technique is a sampling technique with certain considerations.

Table 1. Skema One – Group Pretest-Posttest Design

Pre Test	Treatment	Post Test
X_1	T	X_2

Description
X_1 : Pretest before treatment
T : Treatment
X_2 : Posttest after treatment

Quantitative data obtained from this study are student test scores and student responses. Test scores were obtained through the test method using test question instruments, this instrument was measured by pre-test and post-test. The instrument used is a test containing descriptive questions totaling 5 items related to mixed fraction material. To assess student responses, there are five assessment indicators, namely 1) Exploring information regarding the use of learning media, 2) Introduction to PhET simulation learning media, 3) Response to the use of PhET simulation learning media, 4) Collaborating the use of PhET simulation learning media on learning materials, 5) Interest in learning methods. The source of the instrument is used as an evaluation tool to collect data on the test method which in this case is the posttest.

RESULTS AND DISCUSSION

The first stage carried out by researchers is to give pre-test questions to determine the initial ability of students. The pre-test question consists of 5 numbers of questions in the form of descriptions that are done individually. In the pre-test results, of the 21 students, many still needed special guidance and several other students obtained high predicates.

After the pretest, the learning process was carried out by integrating educational games based on the Colorado PhET simulation using a laptop. The researcher gave directions and explanations of mixed fraction material with the help of educational games on the PhET simulation platform, students observed the explanations given by the researcher through the illustrations displayed. The next step is to play games that have been provided on the PhET platform to increase

understanding related to fractions. Then each student took turns simulating fraction material in the PhET Colorado application. The following is an illustration of the simulation of using PhET Colorado:

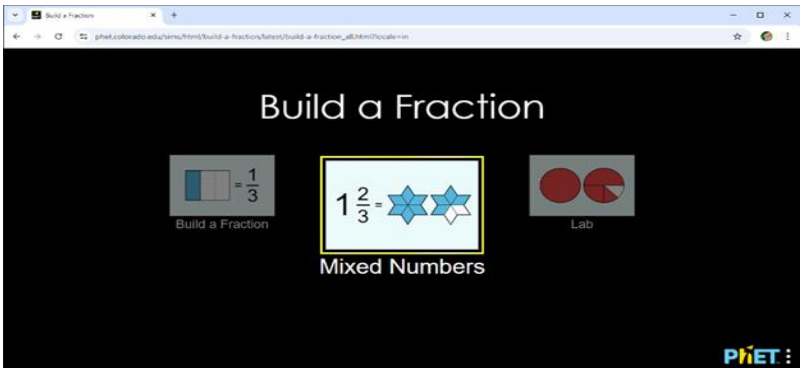

Figure 2. Build a Fraction Start Menu Page

The researcher gave the first simulation example to the students on how to use the PhET platform in determining fractions.

Figure 3. Simulation Menu Selection Page

The researcher chose the first level as a test material to show students how to operate the PhET platform that will be used in the fraction educational game.

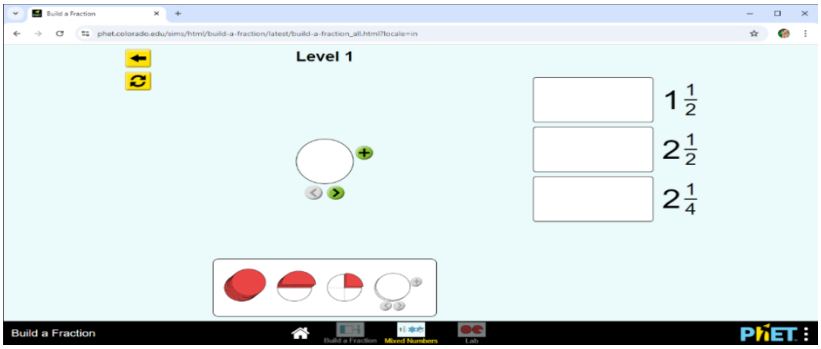

Figure 4. Mixed Fraction Simulation Menu Page

The researcher places the material contained in the lower box into the circle that has been provided according to the problem that has been in the simulation. Furthermore, the materials that have been designed are moved into the box that is already available next to the problem. If the material designed is correct then the design goes into the box and vice versa if the material is wrong then the design cannot enter the box.

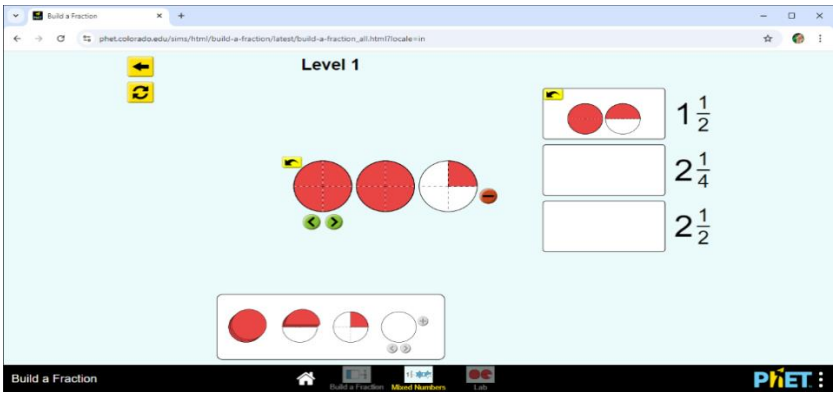

Figure 5. Fraction Trial Simulation Menu Page

Students understand the concepts that have been shown by researchers in playing educational games about fractions, then the researcher asks students how many parts are in the design, after the students understand it, the researcher appoints students to solve the problems contained in the next level.

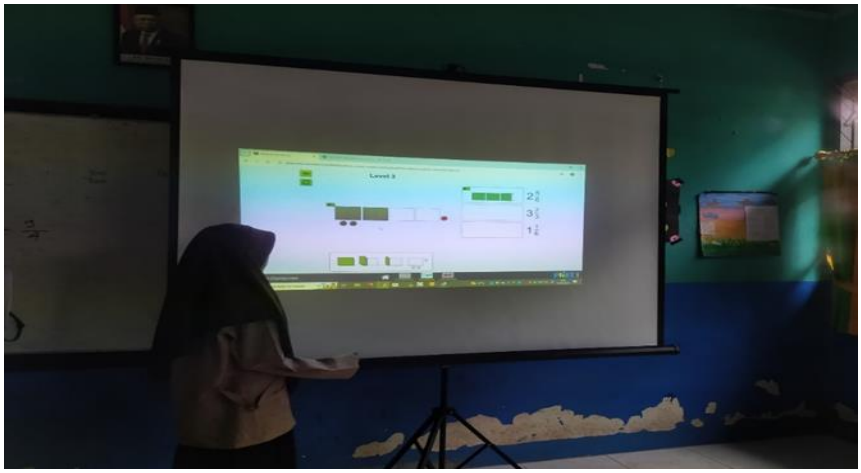

Figure 6. using PhET Simulation media

After the learning process was carried out, the researchers gave post-test questions to determine the final ability of students after the treatment was given,

namely by using PhET Simulation media. The post-test question consists of 5 questions in the form of descriptions that are done individually. The questions used are related to fraction material as previously described with the help of the PhET Colorado platform, then the posttest value will be compared with the previous pretest. The following data were obtained:

Table 2. Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Pretest	21	56	76	68.24	5.726
Posttest	21	75	100	84.62	7.089
Valid N (listwise)	21				

Based on the data above, the results obtained from 21 students who became research samples, the average pretest value was 68.24% and the posttest had an average value of 84.62%. It can be seen that the pretest average < posttest average.

Furthermore, researchers conducted a normality test to obtain data on the results of the pretest and posttest. The normality test is used to show the statistical results are really accurate and can be proven its effectiveness on the use of PhET Colorado interactive media that aims to improve students' understanding of fraction material as shown in the following table:

Table 3. Tests of Normality

	Kolmogorov-Smirnova			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretest	.176	21	.087	.913	21	.063
Posttest	.171	21	.109	.914	21	.065

a. Lilliefors Significance Correction

Based on the results of the normality test above, it can be explained that in the pretest data, the Shapiro-wilk statistic value obtained a value of 0.913, which indicates that the data distribution tends to approach a normal distribution. In addition, with a significance value (Sig.) of 0.063 which is greater than the significance level of 0.05, that the pretest data is normally distributed.

In the posttest data, the Shapiro-Wilk statistic value of 0.914 indicates a possible deviation from normal distribution. In addition, the significance value (Sig.) of 0.065 is greater than the significance level of 0.05. This value indicates that the posttest data is normally distributed at the 0.05 significance level. Therefore, the posttest data distribution follows the normal pattern quite strictly. Based on the results of the normality test, it is known that the significance value is 0.065>0.05, it can be concluded that both pretest and posttest data are normally distributed (pretest: p = 0.03, posttest: p = 0.065).

Table 4. Paired Samples Test

Pair Pretest-Posttest	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	Df	Sign. (2-tailed)
	-16.381	8.880	1.938	-20.423	-12.339	-8.454	21	.000

Based on the results of the t-test differences test, there is a significant difference between pretest and posttest scores at the 0.05 level of significance ($t(20) = 8.454$, $p < 0.001$). The average difference between pretest and posttest scores was 16.381, with a standard deviation of 8.880.

The increase in students' mathematical ability test scores with PhET Simulations on fraction material, students have the opportunity to participate by exploring and manipulating concrete objects as in accordance with Bruner's learning theory and the theory of intellectual development developed by Piaget in the mathematics learning process (Anisatu Rahmah and Fitri Apriyani 2024) fraction material so that they are able to build their own conceptual knowledge about fractions, not from memorization.

The effectiveness of the increase in scores obtained by students proves that PhET Colorado digital learning media has an influence on students' mathematical concept understanding abilities. Not only that, students also get a meaningful learning experience. (Razali and Khalid 2021) The success of a learning activity process is influenced by how the teacher's creativity in delivering the material. With this significant increase, it can be maintained and developed again in learning with the aim that students can continue to develop and be interested in the learning process that takes place. The utilization of PhET

Simulation-Based Educational Games in learning mathematics can be said to be effective because students are more interested in paying attention to the learning that takes place (Arifin, Prastowo, and Harijanto 2022).

Based on the results of the research that has been carried out, there is a positive response from students. However, there are some shortcomings of PhET simulations (Ulul Hidayah n.d.) including 1) The learning that will be carried out must be in accordance with what has been programmed in the PhET application. 2) Students must be able to work independently to follow the learning provided by the teacher. 3) Learners will feel bored if they do not understand how to use a computer, 4) preparation of tools and materials that take lesson time.

Based on the results of data processing, the use of educational games PhET Simulation can be stated as an effective media to improve student learning responses so as to improve student understanding of mathematics lessons on fraction material.

This research is supported by research that has been done (Pangesti and Mulyati 2022). Based on data analysis and discussion of research results, it is concluded that there is a difference between the results of the pre-test and post-test numeracy skills in the experimental class using the PhET Simulations application media on fraction material. The acquisition of the average value of numeracy skills of students in the experimental class is higher than the control class, so it is concluded that the application of PhET Simulations application media on fraction material can improve the numeracy skills of students.

CONCLUSION

From the results of research on the use of PhET Colorado learning media on fraction material, it can be concluded that the media is effectively used to improve students' understanding of mathematical concepts on fraction material. In utilizing this educational game, students have the opportunity to participate by exploring and manipulating concrete objects. This is in accordance with Bruner's learning theory and the theory of intellectual development developed by Piaget in the process of learning mathematics. This study obtained an average pretest score

of 68.24% and the posttest had an average score of 84.62%. It can be seen that the pretest average < posttest average. This study showed that students who used PhET Colorado learning media experienced a significant increase in understanding 0.05 t(20) = 8.454, p < 0.001). The mean difference between pretest and posttest scores was 16.381, with a standard deviation of 8.880.

REFERENCES

Adhi Kusumastuti, Ph. D., Ahmad Mustamil khoiron, M. Pd., Taofan Ali Achmadi, M. Pd. 2020. *Metode Penelitian Kuantitatif*. Semarang: DEEPUBLISH (CV. Budi Utama).

Amir, Almira. 2021. "Penerapan Media Index Card Match Dalam Upaya Meningkatkan Pemahaman Konsep Perkalian Dengan Bantuan Media." *Dirasatul Ibtidaiyah* 1(2):238–50.

Anisatu Rahmah, Ajeng, and Ika Fitri Apriyani. 2024. "Efektivitas Media Phet Simulation Untuk Meningkatkan Hasil Belajar Peserta Didik." *Jurnal Ilmiah Wahana Pendidikan* 10(2):56–62.

Arifin, Mohammad Muhsin, Srihandono Budi Prastowo, and Alex Harijanto. 2022. "Efektivitas Penggunaan Simulasi Phet Dalam Pembelajaran Online Terhadap Hasil Belajar Siswa." *Jurnal Pembelajaran Fisika* 11(1):16. doi: 10.19184/jpf.v11i1.30612.

Arisandy, Debby, Jefri Marzal, and Maison Maison. 2021. "Pengembangan Game Edukasi Menggunakan Software Construct 2 Berbantuan Phet Simulation Berorientasi Pada Kemampuan Berpikir Kreatif Siswa." *Jurnal Cendekia : Jurnal Pendidikan Matematika* 5(3):3038–52. doi: 10.31004/cendekia.v5i3.993.

Faizah, Silviana Nur, Lia Nur Atiqoh Bela Dina, Ari Kartiko, Muhammad Anas Ma'arif, and Moch Sya roni Hasan. 2023. "Student Acceptance Study of Phet Simulation With an Expanded Technology Acceptance Model Approach." *Journal of Applied Engineering and Technological Science* 5(1):279–90. doi: 10.37385/jaets.v5i1.3041.

Hadi, Dian Faisal, Aris Doyan, Jannatin 'Ardhuha, and Ahmad Harjono. 2023. "Influence of the PhET Simulation-Assisted Project-Based Learning Model on Students' Ability to Master the Elasticity Concept." *Jurnal Penelitian Pendidikan IPA* 9(4):1840–45. doi: 10.29303/jppipa.v9i4.3626.

K, Adnan, Muhammad Idris Jafar, Muhammad Irfan, and Musdalifah. 2022. "Hubungan Penggunaan Media Pembelajaran Dengan Minat Belajar Matematika Siswa Kelas IV SD Gugus II." *JIKAP PGSD: Jurnal Ilmiah Ilmu Kependidikan* 6(1):129–37.

Masfaratna. 2021. *Model Pembelajaran Inkuiri Berbantuan Media Simulasi PHET Meningkatkan Hasil Belajar*. Lombok Tengah, NTB: Pusat Pengembangan Pendidikan dan Penelitian Indonesia.

Mayung, Ria Assen, Windy Natalia Tandiayu, Zainuddin Untu, and Aniek Widajanti. 2023. "Seminar Nasional Pendidikan Profesi Guru Tahun 2023 E-ISSN: 2829 - 3541." *Seminar Nasional Pendidikan Profesi Guru Tahun 2021* (2020):105–11.

Nursella, N. 2024. "Pengaruh Penggunaan Media Pembelajaran Interaktif Terhadap Hasil Belajar Siswa SD." *EDUCARE: Jurnal Pendidikan Dan Kesehatan* 4:54–66.

Pangesti, Faradylla Wenas, and Tita Mulyati. 2022. "Efektivitas Media Aplikasi Phet Simulations Dalam Meningkatkan Kemampuan Numerasi Peserta Didik Sd Terkait Materi Pecahan." *Jurnal Pendidikan Dan Pembelajaran ...* 11(229):2715–23. doi: 10.26418/jppk.v11i9.58609.

Rangkuti, Ahmad Nizar. 2022. "Diagnostik Kesulitan Belajar Siswa Pada Materi Aljabar." *AXIOM : Jurnal Pendidikan Dan Matematika* 11(2):116. doi: 10.30821/axiom.v11i2.13310.

Razali, Nur Hafizah, and Fariza Binti Khalid. 2021. "Penggunaan Aplikasi Pembelajaran Mudah Alih Dalam Pembelajaran Matematik Bagi Pelajar Sekolah Menengah." *Malaysian Journal of Social Sciences and Humanities (MJSSH)* 6(6):73–85. doi: 10.47405/mjssh.v6i6.812.

Sirait, Syarif Hussein, Jessicha Putri, Br Ginting, and Seminta Br Sembiring. 2023. "Pengaruh Penggunaan Media Simulasi Phet Terhadap Hasil Belajar Materi Pecahan Siswa SD 056604 Purwobinangun." *Jurnal Curere* 7(2).

Susilawati, Anjar, Tia Dita Putri, and Alfiah Nursangadah. 2022. "Penerapan Simulasi PhET Pada Pembelajaran Matematika Di Kelas III SDN Trayu." *Pendas : Jurnal Ilmiah Pendidikan Dasar* 7(2):949–60.

Ulul Hidayah, Dkk. n.d. "Efektivitas Media Phet Simulation Terhadap Kemampuan Numerasi Siswa Kelas 5 SDN Jatingaleh 01 Pada Mata Pelajaran Matematika." 5(3):1–23. doi: https://doi.org/10.55681/nursa.v5i3.3211.

Uwambajimana, Sylvere, Evariste Minani, Abraham Daniel Mollel, and Pascasie Nyirahabimana. 2023. "The Impact of Using PhET Simulation on Conceptual Understanding of Electrostatics within Selected Secondary Schools of Muhanga District, Rwanda." *Journal of Mathematics and Science Teacher* 3(2):em045. doi: 10.29333/mathsciteacher/13595.