



## Physics Education Technology Project (PhET) : Interactive Simulation to Improve Students' Understanding of Concepts and Perceptions

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**Abstract:** This study aims to analyze 1) the effect of PhET Gene Expression on students' conceptual understanding and 2) students' perceptions of the Gene Expression Essentials simulation. The research method used was Quasi Experiment with a quantitative approach. The research design used a one-group pretest-posttest design. In the treatment phase, students learned using gene expression simulations from PhET simulations. Data on students' understanding of concepts were obtained from tests and perceptions using a questionnaire. Data analysis used the t-test with the help of SPSS 23 and descriptively. The Paired sample t-Test analysis results showed that the significance was  $0.000 < 0.05$ . Students stated that PhET in motivation, effectiveness, benefits, and presentation had high interpretations. Based on the research that has been done, PhET Gene Expression Essentials influences students' understanding of concepts, and students respond positively to PhET Gene Expression Essentials.

### Article History

Received: 23-05-2023  
Revised: 14-06-2023  
Accepted: 25-06-2023  
Published: 17-07-2023

### Key Words:

Gene Expression; PhET;  
Interactive Simulation;  
Perceptions.

**How to Cite:** Samitra, D., Firdaus, M., & Krisnawati, Y. (2023). Physics Education Technology Project (PhET): Interactive Simulation to Improve Students' Understanding of Concepts and Perceptions. *Jurnal Paedagogy*, 10(3), 646-654. doi:<https://doi.org/10.33394/jp.v10i3.7879>



<https://doi.org/10.33394/jp.v10i3.7879>

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## Introduction

Genetics is part of Biology that provides an understanding of how living organisms function and evolve and how they work (Nurse & Hayles, 2019). It causes genetics to be mandatory material that must be studied in biology. Despite the importance of its mastery, Genetics is one of the materials that often causes misconceptions in Biology lessons (Osman et al., 2017; Stern & Kampourakis, 2017). Genetics is also very difficult in Indonesia and several countries (Fauzi et al., 2021). That is because genetic material has many unfamiliar terms and is considered difficult by most students because this material is abstract. Concepts are considered abstract if students do not have clear references presented in their thinking (Bolognesi & Vernillo, 2019). In addition, the genetics learning process is still teacher-oriented, using lecture methods, teacher explanations, little discussion, and a lack of technological involvement in providing learning facilities (Casanoves et al., 2017). One of the materials in genetics is gene expression.

Gene expression learning should present the material so that students can easily understand it. However, learning gene expression is tedious and challenging due to abstract material concepts. Students consider genetic material difficult and abstract (Çimer, 2012; Hadiprayitno et al., 2019). That is because students cannot construct the material as a whole or connect between concepts. Several solutions have been developed to overcome this, namely video and virtual animation.

One of these animations is Gene Expression Essentials, developed by the Physics Education Technology Project (PhET), University of Colorado. PhET Simulation is a project at the University of Colorado that develops simulation tools that focus on learning physics (Yuliati et al., 2018). Previous research stated that some of the common problems experienced by students, namely low knowledge and metacognitive skills, can be solved through simulation (Correia et al., 2019). In addition, computer animation can help concretize abstract and complex concepts and phenomena in science education, thus helping students learn more easily and effectively (Akpınar, 2014).

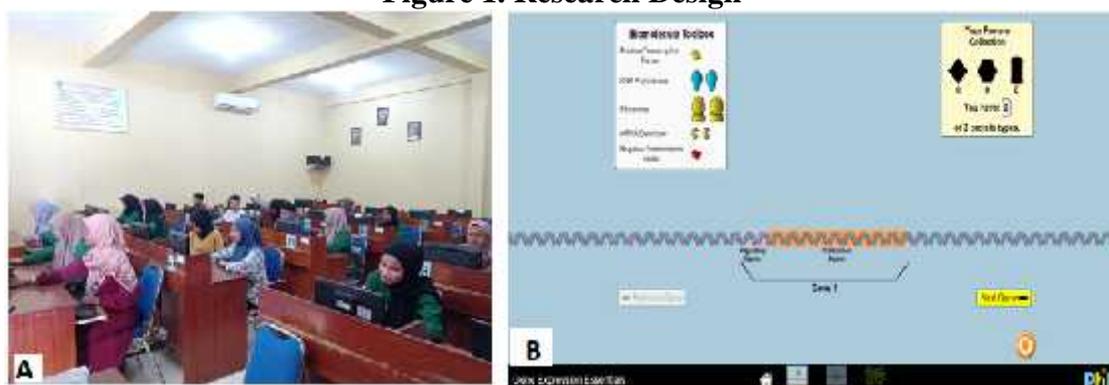
The results of previous research showed that PhET increased cognitive learning outcomes (Verawati et al., 2022), improves science process skills (Haryadi & Pujiastuti, 2020), increased students' understanding of concepts (Inayah & Masrurroh, 2021). The PhET Gene Expression research was conducted by Gregório et al. (2016) limited to public high school students and the results were that students became more active. Therefore, this study uses PhET Gene Expression at the university level and aims to analyze 1) the effect of PhET Gene Expression on students' conceptual understanding and 2) students' perceptions of the Gene Expression Essentials simulation.

### Research Method

The research method used was Quasi Experiment and quantitative approach. The research design used a one-group pretest-posttest design (Figure 1). This research was conducted at PGRI Silampari University. A total of 36 students became participants. In the treatment phase, students learned using gene expression simulations from PhET simulations (Figure 2).



**Figure 1. Research Design**



**Figure 2. A. Students were using PhET Gene Expression Essentials. B. PhET Gene display (from: <https://phet.colorado.edu/en/simulations/gene-expression-essentials>)**

Data on students' understanding of concepts were obtained from tests and perceptions using a questionnaire. The questionnaire framework was based on Putra et al. (2021) for a closed questionnaire using a Likert scale of 1-5 and Correia et al. (2019) for an open questionnaire. Closed questionnaire interpretation criteria (Table 1) were based Nurdiyanti et al., (2021). Data analysis used the t-test with the help of SPSS 23.



**Table 1. The criteria for interpretation**

Value	Category
$1 < R < 2$	Very Low
$2 < R < 3$	Low
$3 < R < 4$	Medium
$4 < R < 5$	High
$R = 5$	Very High

## Results and Discussion

### Students' Concept Understanding

The pretest results showed that the average student score was 15.51, and the posttest average score was 86.85 (Table 2). The Paired sample t-Test analysis results showed that the significance of 2 tailed was 0.000 < 0.05 (Table 3); this showed a difference between the average pretest and posttest values.

**Table 2. Results of analysis of pretest and posttest values**

Item	Pretest	Posttest
Mean	15.51	88.85
Minimum	9.33	77.33
Maximum	21.33	97.33
Deviation Standard	3.07	4.26

**Table 3. Results of analysis of Paired sample t-test**

t-test	df	sig
84.83	35	0.000

The average value of the pretest and posttest was different due to the treatment carried out by the researcher. The treatment was using PhET Gene Expression Essentials animation in learning. This research aligns with previous research results where simulation learning can increase conceptual understanding (Brophy et al., 2013; Price et al., 2016; Schwedler & Kaldewey, 2020). That is because PhET simulation media provides concepts and invites students to find the concepts in reality (Mariko, 2021). Simulation learning can support students with low understanding and cannot construct abstract concepts (Olympiou et al., 2013). The existence of simulation learning helps abstract understanding to be easily understood. That is because animated media can provide a comprehensive experience from concrete to abstract. Animation media can also embed basic concepts that are true, real and precise. Besides that, it can generate motivation and stimulate students to study well (Lau & Lee, 2015; Salam et al., 2020). It is in line with the thinking Sihombing et al. (2021) that better student learning motivation, better student understanding of concept

The function of the media is considered good when the message follows the intended message's essence, so it is necessary to choose relevant media to help channel the message properly (Budiyono, 2020). Technology is closely related to modern life. Technology is essential in educational activities (Nirbita & Sartika, 2021). The use of media with modern technology is necessary for learning.

### Student perceptions

Student perceptions after using PhET Gene Expression Essentials are in Table 4. All aspects get high interpretations. The motivational aspect has the highest average value of 4.89, while the lowest average value is the presentation aspect of 4.15.



**Table 4. Student perceptions after using the PhET Simulation**

Aspect	Average	Interpretation
Motivation	4.89	High
Effectiveness	4.54	High
Benefits	4.64	High
Presentation	4.15	High

PhET Gene Expression Essentials can motivate learning. This result is in line with the statement of Bower et al. (2014) and Inayah & Masruroh (2021) simulated learning in class causes student learning motivation to increase. Good learning motivation positively affects learning outcomes (Froiland & Worrell, 2016; Lin et al., 2017). Motivation becomes one of the most essential factors in learning (Mohammad-Davoudi & Parpouchi, 2016). Students motivated to learn will affect the learning outcomes because their understanding of the concept will improve. It can happen because research-based science is interactive, fun and free, which can be used to increase the effectiveness of teaching and learning (Sylviani et al., 2020).

PhET Gene Expression Essentials is effective and useful for learning protein synthesis. That is because protein synthesis is abstract, so students need help understanding if not assisted by learning media. Simulation media can help to learn by increasing learning activities and helping understand abstract concepts (Lindgren et al., 2016; Sastradika et al., 2021). Motivating to learn, effective to increase understanding, useful. It is consistent with the benefits of simulated learning media, namely increasing motivation, providing learning experiences, and helping understand abstract concepts.

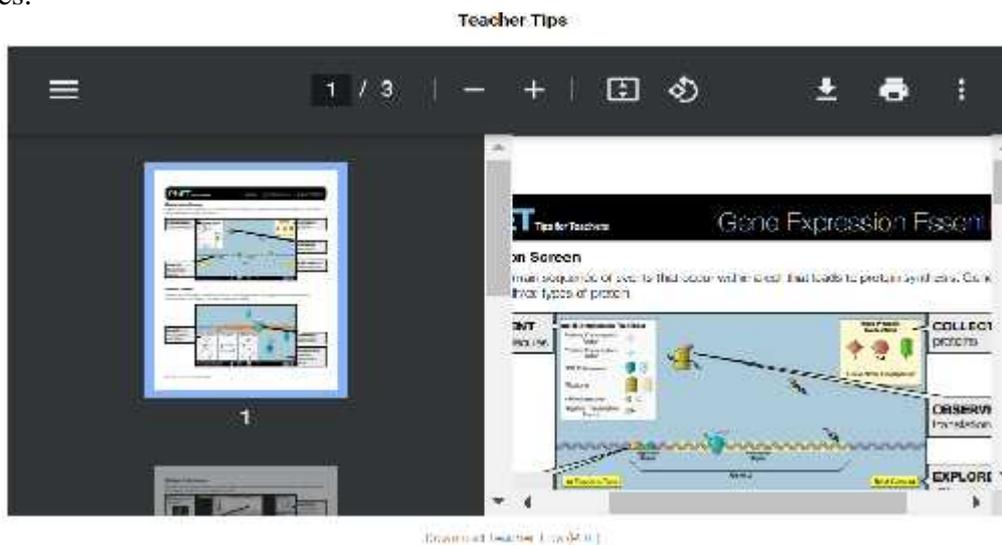
**Table 5. Difficulties encountered in using PhET**

Aspect	Percentage (%)
Language	63.89
No user guided	36.11

PGRI Silampari University Biology Education student stated difficulties were still encountered using PhET simulations (Table 5). For Indonesian, the development team has made options for users to choose various languages, but the menu is not perfect because the language is still mixed with English. PhET simulation is not fully user-friendly because there is no guide on how to use the simulation. PhET only provides teacher tips for users with an account (Figure 3). To overcome this, the researcher gave directions on using the simulation before students used the PhET simulation.

Students think that PhET can help learn the concept of gene expression by helping to understand the concept 75.00%, motivating to learn, 16.67% and having animation makes learning fun 8.33% (Table 6). Animation and simulation are essential in visualizing the sub-microscopic level (Fang & Guo, 2016; Liu et al., 2021). It allows students to learn the concept of protein synthesis quickly. PhET Interactive Simulations require improvements or additional features to help students better understand conceptual understanding through analogies of product and reactant molecules' movement in the equilibrium system (Rahmawati et al., 2022). An interactive simulation is a helpful tool for improving student understanding (Moore et al., 2014). Students become enthusiastic and active in learning because students learn with the help of audio-visual media to improve learning outcomes (Kibtiyah & Iba, 2022; Selamet, 2020). Daniar & Sari (2022) added that the existence of technology-based media is also effective in helping the learning process.

PhET simulation media can make students interested and enthusiastic (enhancement of learning motivation) in the learning process and provide students with an understanding of abstract concepts (Susilawati et al., 2022). There are exciting activities in the learning process, which also causes the PhET simulation media to become an alternative media which presents interesting pictures in the learning process. Consequently, the students are interested in the following learning (Diraya et al., 2021). In addition, according to Hidayat & Subekti (2022), using PhET can improve science process skills and student learning outcomes.



**Figure 3. Teacher Tips provided by PhET (from <https://phet.colorado.edu/in/simulations/gene-expression-essentials/teaching-resources>)**

**Table 6. Student comments about how the program helps them learn the concept of Gene Expression**

Aspect	Percentage (%)
Help understand the concept	75.00
Motivates to learn	16.67
Animation makes learning fun	8.33

Students of Biology Education, PGRI Silampari University, assess that several things need to be improved, namely the existence of a guide for use in the Indonesian language (Table 7). The PhET simulation has provided a guide for using Indonesian language teachers and menus, but it is imperfect.

**Table 7. Student comments on what needs to be improved for the PhET simulation**

Aspect	Percentage (%)
User guided	54.17
Indonesian Language	33.33

This research has conceptual implications that students can construct an understanding of gene expression material. It is in accordance with research by Safarati (2017) which showed that the use of PhET media could help students understand visual concepts and foster students' critical thinking skills on phenomena that were classified as abstract. Learning using PhET media also has a high average motivation. High motivation will improve the skills of student learning outcomes. Faizi (2013) suggested that the use of media in learning activities



was able to attract student learning interest so that students' attention to learning material increases. In addition, this research serves as input for lecturers so that learning is abstract and needs to be assisted with interactive teaching media to make it easier for students to understand the concept. PhET media also motivated lecturers to improve their foreign language skills.

### **Conclusion**

Based on the research that has been done, PhET Gene Expression Essentials improve students' understanding of concepts, and students respond positively to PhET Gene Expression Essentials. The simulation can motivate learning, encourage students to learn more, provide experiences, have fun, and help them understand abstract concepts. In future, PhET developers need to add an Indonesian language usage guide and simulation.

### **Recommendation**

In the future, PhET developers must add an Indonesian language usage guide and simulation. Visual media should assist abstract learning. Further research can be conducted by comparing classes using simulation and video media. Recommendations for teachers or lecturers so that learning is abstract, it needs to be assisted with interactive teaching media to make it easier for students to understand concepts. In addition, because PhET media is in English, teachers and lecturers must prepare lessons carefully so that the teaching and learning process runs well.

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