CELL CYCLE EXPLORER: A DRAG-AND-DROP SIMULATION FOR CONCEPTUAL UNDERSTANDING OF MITOSIS

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ABSTRACT

Cell Cycle Explorer is a simple drag-and-drop simulation to promote conceptual learning about mitosis among students. The procedure is based on interactive features allowing the user to control different steps of the cell cycle enabling to see and interact with DNA replication, chromosome alignment, and segregation during mitosis. Key results show that students who exploited the simulation performed better in terms of understanding of more complex mitotic events as opposed to conventional instructional approaches, as demonstrated by the higher test scores and the amount of information retained. Drawing from this research, the conclusion that interactive simulations such as Cell Cycle Explorer have a profound effect on biology learning outcomes in the classroom is that they are also a powerful tool for improving learning in biology education. It is recommended that such simulations be incorporated into standard course curricula to promote more robust conceptualization and engagement with biological principles, especially among visual and kinesthetic learners

Keyword: *simulation, cell explorer, cell cycle, mitosis, drag-and-drop*

1. Introduction

Interactive teaching is an instructional method that stresses active participation and involvement of the students, in contrast to conventional lecture-based teaching. When educators include, e.g., group discussions, simulations and hands-on experiences, teaching is such that it is responsive to the varied learning styles of the learners. This approach greatly improves student involvement and motivation, and as a result, leads to higher levels of academic achievement and retention of knowledge. Simulations and hands-on activities are critical in this phase, by offering experiential learning experiences that enable the application of theoretical knowledge in real situations. These interactive features encourage thinking, working together, and communicating, while students collaborate to find solutions to problems and make decisions concerning the content they are studying. Interactive teaching not only makes the learning experience richer, but also prepares students for future problems by giving them necessary skills regarding their life or career.

A Drag-and-Drop Simulation for Conceptualizing Mitosis attempts to provide an answer to the teaching problems in the educational context of mitosis and the cell cycle-related processes. The increasing emphasis on science education globally, particularly in the context of a rapidly evolving biotechnology landscape, necessitates innovative pedagogical tools that can enhance student engagement and comprehension (Harris et al., 2019). Traditional teaching strategies, however, are often based on passive learning strategies that have been linked with cellular process misconceptions (Miller Smith, 2021). This study is grounded in constructivist learning theories, which advocate for active learning environments where students can explore and manipulate scientific concepts through interactive simulations (Gonzalez et al., 2020).

Several studies published in the past few years have shown the effectiveness of simulation-based learning in biology education. Studies have shown that, for example, the Cyclone package and Cycler are capable of automatically assigning the stage in the cell cycle as well as of characterizing the single cell activity in the cell cycle, using single-cell RNA sequencing (scRNA-seq) and imaging (Teichmann et al., 2017). These advances emphasize the utility of the simulation toolbox for generating more nuanced understandings of cellular dynamics and in enhancing educational experience. Cell Cycle Explorer extends this basis in the sense that it provides a drag-and-drop interface for students for visualizing and manipulating mitotic stages and thereby promotes a deeper appreciation of the inherent biological significance of these important biological processes. The integration of technology in education has been shown to foster engagement and enhance learning outcomes (Rochester Medical Center, 2022). In the United States, there is a pressing need for effective strategies to teach complex biological concepts, particularly in the context of rising cancer rates linked to cell cycle dysregulation (Open Oregon State, 2021). This study is framed by constructivist learning theories, which posit that students learn best through active participation and experiential learning. Interactive simulations allow learners to visualize and manipulate biological processes, thereby facilitating deeper understanding and retention of knowledge (Nature Education, 2021). Additional studies have explored various pedagogical approaches; the use of drag-and-drop simulations has been linked to increased student engagement and motivation in learning about cellular processes (Open Oregon State, 2021), while investigations into hands-on modeling activities demonstrate their effectiveness in reinforcing theoretical knowledge through practical application (Nature Education, 2021).

The main goal of this study is to show the effectiveness of the Cell Cycle Explorer in teaching mitosis concepts. The present study has been designed not to be a blank slate, but to use a rigorous assessment framework to show the potential of interactive simulations to achieve better learning efficacy and knowledge retention. In the end, the study aims not only to enrich biology learning, but also to provide insights for the design of future educational technologies of which can be utilized in many scientific fields.

1.1 Statement of The Problem

This research study aims to show the effectiveness of the drag-and-drop simulation in enhancing students' comprehension, motivation and engagement on mitosis. This research is designed to address the following questions:

1. What is the current level of students' understanding of the cell division-mitosis before using the simulation?
2. How drag-and-drop simulation increased the students' engagement and motivation?
3. What enhanced drag-and-drop simulation for conceptual understanding of mitosis?
4. Is there a significant improvement in students' conceptual understanding of mitosis after participating in the game-based simulation activity as measured by pretest and posttest scores?

1.2 Framework of the Study

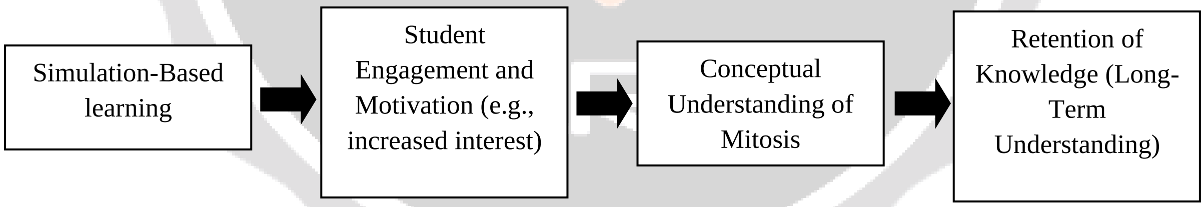


Fig -1: Conceptual Framework

Results of this study can be used as a baseline for the science educators to maximize the use of other learning strategies such as simulations and other interactive activities to enhance teaching and learning process. This could also a gateway to understand the needs of diverse learners and use appropriate strategies and materials for them to have a long-term understanding.

2. Research Methodology

2.1 Research Design

The study employs a quantitative descriptive-survey research design. This method is applicable to the evaluation of the efficacy of the Cell Cycle Explorer simulation to teach Grade 8 students' knowledge of cell cycle concepts. In the study, a standardized questionnaire will be used to collect the information about students' attitudes and learning results for the simulation. This kind of design permits statistical assessment of responses, thereby making it easy to determine the effect of the applied simulation on the learning of students.

2.2 Locale of the Study

The study will take place in Tagbina National High School particularly Grade 8 learning group since the researcher has only one load of science subject. Significant is the choice of this site, as it offers the chance to test the simulation's utility in an intervention setting and thus gain specific information on its potential and effect.

2.3 Data Gathering

Data will be collected through a combination of methods such as administered a structured standardize pre-test and post-test questionnaire from the region office to all participants to gather quantitative data to measure knowledge gain using experiences with the Cell Cycle Explorer simulation; permission letter address to the principal for the implementation of innovation; parent consent is also given to the students before the implementation; observations towards students engagement and behavior can be conducted during the course of the simulation; and conduct of survey for innovative drag-and-drop simulations structured by the researchers to collect data on learners satisfaction with the innovation and would be useful to evaluate effectiveness and user experience. The survey includes 8 statements focusing on the aspects such as the design interface of the innovation, visual aspect such as the layout and graphics and experiences of learners when manipulating the simulation. Below is the printed satisfaction survey and was distributed to 30 students and answered immediately:

Table -1: Satisfaction Survey Questionnaire

Statements	5 (Strongly Agree)	4 (Agree)	3 (Neutral)	2 (Disagree)	1 (Strongly Disagree)
1. The game-based simulation was an innovative and engaging way to learn the material.					
2. I found the drag-and-drop mechanics in the simulation to be an effective way to interact with the content.					
3. The simulation was easy to navigate and use.					
4. The game-based simulation enhanced my understanding of the topic or concept being taught.					
5. The simulation's design (graphics, layout, etc.) contributed positively to my learning experience.					
6. The simulation was an enjoyable and fun learning experience.					
7. The feedback and instructions provided during the simulation helped me understand how to improve my performance.					
8. Overall, I am satisfied with the innovation of the game-based simulation.					

2.4 Data Analysis

Data analysis will involve quantitative methods. For Quantitative Analysis statistical methods will be employed to interpret survey data, especially measures: mean values, standard deviations, and correlation values, to evaluate the association between the use of simulation and learning results. As to the data result of the satisfaction survey, weighted average of each statement is calculated to provide an overall score of each statement and interpret it using ranges: 4.5-5.0 (Very Satisfied), 3.5-4.4 (Satisfied), 2.5-3.4 (Neutral) and 1.5-2.4 (Dissatisfied). The overall result also of the survey will be shown through a bar graph as visual presentation of the frequency of responses of learners in each statement.

2.5 Demographic Profile of the Respondents

The research population will consist of Grade 8 students from Tagbina National High School, that is, a demographic of students roughly 13 to 14 years old, with a total of 30 students of both genders. Also, academic history of the respondents will be examined to measure their prior biology knowledge, thereby enabling us to understand their simulation responses.

3. Result and Discussion

Games and simulations create structured environments that engage students, motivating them to explore content meaningfully. According to Lewis et al. (2013), the primary goal of using games in education is to foster learner engagement and motivation, which are critical for effective learning outcomes (Lewis, Lancaster, Savenye, & Haas, 2013). Before the implementation of the simulation, learners gained low scores in their pretest that indicates low comprehension of the lesson. The study "Cell Cycle Explorer: A Drag-and-Drop Simulation for Conceptual Learning of Mitosis" demonstrated a statistically significant higher comprehension of mitosis as evidenced by the significant difference between pre-experimental and post-experimental scores. This simulation-based approach to learning allowed students actively to learn the material and thus achieve a deeper level of conceptual understanding of cell cycle dynamics. Results indicated that students gained significantly in mitosis knowledge after simulation. Pre-test scores were significantly lower than those of post-test, which indicates the interactive characters of the simulation could significantly improve the learning result. In the drag-and-drop component of the game, it delivered learners dynamic teaching experience, in that the learners could observe and "play around" the steps of mitosis, which both facilitated the retention and comprehension.

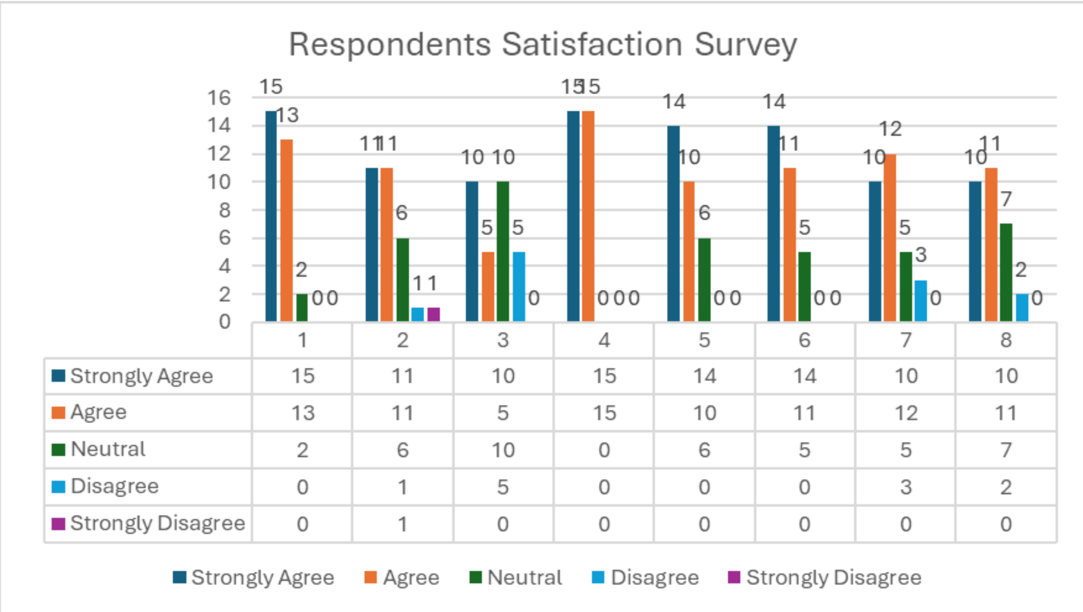
Table -2: t-Test: Paired Two Sample for Means (Pre-Test and Pot-Test)

	Variable 1	*Variable 2*
Mean	7.8	12.6
Variance	4.648275862	11.42068966
Observations	30	30
Pearson Correlation	0.215811574	
Hypothesized Mean Difference	0	
df	29	
t Stat	-7.3130926	
P(T<=t) one-tail	2.34612E-08	
t Critical one-tail	1.699127027	
P(T<=t) two-tail	4.69223E-08	
t Critical two-tail	2.045229642	

The statistical test revealed a significant variance between means of Variable 1 (mean 7.8) and Variable 2 (mean 12.6). The t -statistic -7.3131) and extremely low p -values (approximately 2.35 x 10^-8 in one-tailed and 4.69 x 10^-8 in two-tailed tests) give strong evidence of rejecting the null hypothesis (no mean difference). This evidence suggests that Variable 2 is markedly greater than Variable 1 and therefore clearly and importantly different in their means. In the study of Matyakhan, T., Chaowanakritsanakul, T., & Santos, J. A. L. (2024) who conducted a study that demonstrated the positive effects of gamification on reading engagement and comprehension among Thai EFL university students. Their findings indicated that students who participated in a gamified learning environment showed significant improvements in reading comprehension compared to those in traditional settings, highlighting the effectiveness of gamification in fostering a more engaging and interactive learning experience. During also the implementation as to the general observation towards the learners, some students faced challenges in manipulating the laptops and following instructions, leading to initial confusion regarding the gameplay sequence. But, in the simulation, students exhibited a high level of attention. As they progressed and began to grasp the correct sequences, their satisfaction grew, particularly when they successfully completed various stages of the game. Teacher status was most important, as she kept reminding and talking about the game content, which reinforced knowledge and sustained interest. This active method can not only help the students to cope with challenges but also motivate them to actively participate in the discussions of the cellular processes. Although there were some early challenges in terms of technology adoption and understanding of playing the game, the whole experience of “Cell Cycle Explorer” proved to be a learning tool that promoted not only motivation but also a better conceptual understanding of underlying biological problems as students repeatedly revisited parts to achieve higher score. According to Hainey et al. (2013), the effectiveness of games and simulations in education lies in their ability to create structured environments where learners can explore content meaningfully while making decisions in risk-free settings. This approach not only enhances comprehension but also supports problem-solving skills.

3.1 Discussion on Survey Result

According to the study of Hawlitschek, 2017 that digital educational games positively influence students' motivation for learning. This research indicated that the simulation creates a contextualized learning environment, which enhances understanding and mastery of knowledge while stimulating interest and motivation to learn. This provided interesting findings regarding the effectiveness of a digital game-based learning application for improvement of student understanding on mitosis. The satisfaction survey findings showed acceptance (weighted average score 4.11) in which students expressed their satisfaction with usability and educational contribution of the simulation.



	1	2	3	4	5	6	7	8
Strongly Agree	15	11	10	15	14	14	10	10
Agree	13	11	5	15	10	11	12	11
Neutral	2	6	10	0	6	5	5	7
Disagree	0	1	5	0	0	0	3	2
Strongly Disagree	0	1	0	0	0	0	0	0

Fig -2: Respondents Satisfaction Survey

Satisfaction survey results in the current study showed a weighted mean score of 4.11 which is a high level of satisfaction of surveyed respondents. This score indicate that students rated the simulation as both very engaging and very effective for the development of student knowledge of mitosis. This positive reinforcement is not restricted just to the utility of the tool (or the user) but it also is the capacity of the tool to drive the process of the learning (interactive gameplay). Based on the study of Wang et al. (2022) found that students' experiences with feedback and challenge in gamified content were positively correlated with their learning outcomes, suggesting that well-designed gamified environments can enhance comprehension by providing timely feedback and maintaining student interest.

Students reported feeling more motivated and engaged while using the simulation, as it allowed them to visualize complex biological processes in a dynamic and interactive environment. The strong (good) survey answer score is due to multiple issues including the natural design of the drag-and-drop interface allowing students to easily move the elements around even if they encountered some problems with technology at first.

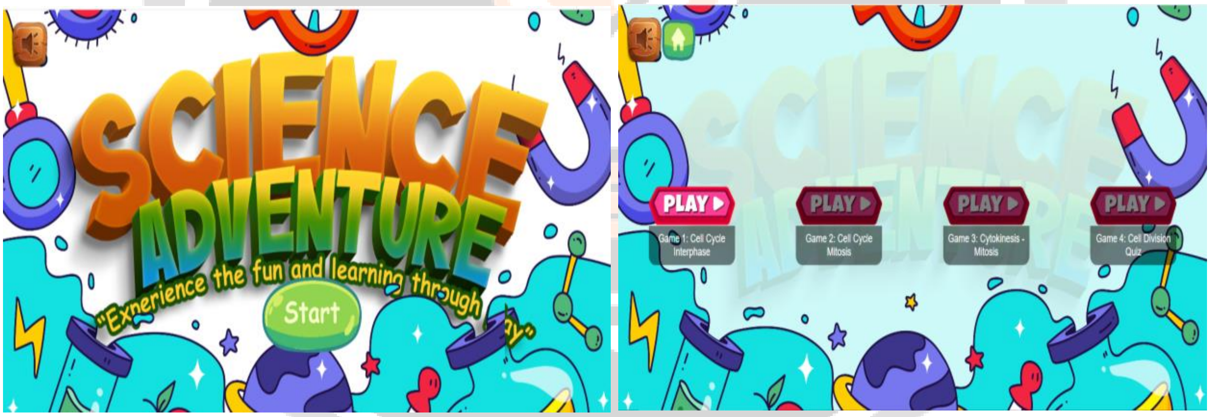
In addition, the survey findings indicate that students enjoyed the possibility to return to the parts in which they got wrong, especially for puzzle-related elements. This repetitive learning process not only strengthened their knowledge, but also induced a feeling of achievement and progression in being able to pass to the next level of the game. In addition, the role of teacher is not only in leading the dialogue about the simulation but also how they may be read as "reminder notes" also played a role in making the students participatory and pleasant atmosphere, attention and engagement with the simulation. In contrast, a weighted mean of 4.11 is a meaningful index of the impact of the simulation on motivating the concept acquisition of mitosis, an improvement on the quality of students' experience and relative satisfaction with the learning task.

3.2 Game-Based Simulation Design Overview

Game-stimulation is a new educational strategy which is a combination of gaming and simulation features to cater for modern experiential learning. The learners move closer to real-world scenarios in a safe, secure environment: They can meaningfully engage with the complexity of learning, thereby promoting understanding of those concepts and the acquiring of certain skills. Important features of it include interactivity, realism, and orientation towards goals: these keep the learner interested and focused on his task. The advantages of game-based simulation are tangible because they increase student involvement and retention of knowledge and build crucial 'softer' skills such as teamwork and communication. Such wide-ranging applicability across educational qualifications and subjects-from technical education through STEM fields to social sciences-makes game-based simulations adaptable to learning outcomes. Standards in effective design considerations, addressing cognitive engagement, aligning content with educational standards, and developing feedback for assessment purposes. All in all, game-based simulations can prove themselves as one of the most powerful weapons of modern education as it enables the active learning of students within an immersed experience to face the realities of the real world.

3.3 Representation of the Game-Based Simulation

The contextualized game-based simulation of mitosis that incorporates a simple drag-and-drop action offers students an exciting and interactive opportunity to learn about the complex biological process. This simulation allows students to move the cellular components around and visualize each phase of mitosis such as prophase, metaphase, anaphase, and telophase through active participation. Every click of the cell parts images has a corresponding definition and its role in a specific phase of mitosis. This is followed by a short overall discussion after completing each stage, which reiterates vital areas and underlines theoretical links to the interactive experience. Learners cannot proceed to the next level of the game once they will not get the correct pattern of arranging the cell parts. At the last segment, students are given a short quiz and therefore given an opportunity to evaluate their grasp of the material, which in turn heightens retention and creates true interest in biology. It will benefit not just learning by making it fun, but also improved retention and disposition.



https://ucadz.github.io/celldivision/Home.html

Fig -3: Science Adventure on Mitosis Game-Based Simulation

4. CONCLUSIONS

The study objective was the assessment of the effectiveness of a computer simulation for the acquisition of the cell cycle, with a special focus on mitosis. In an interactive drag-and-drop paradigm, the current work aimed at attracting learners to a truly hands-on learning experience with the goal to inform and improve the conceptual comprehension of certain complex biological processes.

Results from the satisfaction survey reported a mean satisfaction score of 4.11, denoting a high level of satisfaction of students with the simulation. As students explained, the tool led to greater involvement and motivation, with interactive use of the tool and the chance to observe mitotic processes being particularly well received by participants. Observations during gameplay revealed that, despite initial challenges with technology and gameplay mechanics, students became focused and enthusiastic as they progressed through the simulation. They showed delight on completion of stages and expressed a willingness to repeat parts to enhance comprehension wherever they faced a problem.

On this basis, it is concluded that digital simulations such as Cell Cycle Explorer have the potential to make an important contribution to improving learning by students in biology teaching. The potential ontological extensions to theoretical models indicate that interactive learning tools can help to fill lacunae in conventional educational approaches by offering experiential learning experiences tailored to different ways of learning. This research highlights the necessity of embedding technology within the curriculum, because not only it can help stimulate engagement, but also it can encourage more elaborate cognitive processing of abstract ideas.

Future directions for this work could be to increase the sample size and diversity of the sample, to more robustly generalize the results obtained. Additionally, addressing the constraints and overcoming to some students' initial technological challenges can increase the effectiveness of the simulation. Future versions may also be developed with broader student and teacher training in how and when to use the technology effectively. Moreover, research into long-term retention of information acquired in such a simulation might provide a further insight into the utility as a pedagogical tool. Overall, while the present work highlights the crucial benefits of digital simulation in teaching mitosis, this will be key to both future research and implementation study.

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