



Influence of Computer Simulations on Academic Performance in Biology in Public Secondary Schools in Kesses Sub-county, Kenya

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Abstract: *Biology plays a pivotal role in shaping scientific understanding and improving human welfare. However, in Kenyan Public Secondary schools continue to record low performance in the subject, expansively due to teacher-centred instructional approaches. This study examined the influence of computer simulations on students' academic performance in Biology in public secondary schools in Kesses Sub-county, Kenya. The research was guided by the Constructivist Learning Theory, which emphasizes active learner participation and knowledge construction through interactive experiences. A mixed methods approach was employed by integrating a quasi-experimental Solomon four-Group design with a survey. The study involved 240 form three students drawn from four co-educational schools. Experimental group was instructed with computer simulations, while control group was taught using conventional methods, over six week-periods. Data were collected through pre-tests, post-tests, questionnaires, and classroom observations, and analyzed using descriptive statistics, paired t-tests, and ANOVA. Findings indicated that computer simulations significantly improved students' academic performance, conceptual understanding, and engagement in Biology. The study concludes that simulation-based teaching can transform Biology learning by making it more interactive and effective. It recommends that the Kenya Institute of Curriculum Development and the Ministry of Education promote the use of computer simulations and train teachers to integrate them meaningfully in classroom.*

Keywords: *Computer Simulations, Academic Performance, Biology Practical, Technology Integration, Secondary Education, Kenya*

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1. Introduction

Science education is the foundation of innovation, critical thinking, and national development. It equips learners with the ability to question, explore, and apply scientific knowledge to real-life situations (Vieira & Tenreiro-Vieira, 2016). Among the sciences, Biology

occupies a central role that learners understand life processes and prepare themselves for careers in medicine, biotechnology, and environmental science. Beyond professional relevance, Biology enables students to make informed decisions about health, nutrition, and the environment, all of which directly affect human well-being.

Despite its importance, many students in Kenyan secondary schools continue to perform poorly in Biology. Reports by the Kenya National Examinations Council (KNEC, 2018; Obonyo, 2023) show a persistent trend of low achievement. One of the key reasons for this has been the continued over-reliance on teacher-centered instructional methods such as lectures and rote memorization. These traditional approaches often leave students as passive listeners rather than active participants, limiting their ability to understand and apply scientific concepts meaningfully (Srivastava, Kumari & Gond, 2020). As a result, complex topics like genetics, reproduction, and physiology remain difficult for many learners (Orodho, 2022).

In Kenya, initiatives such as the Strengthening of Mathematics and Science Education (SMASE) program through the Centre for Mathematics, Science, and Technology Education in Africa (CEMASTE) have promoted the use of learner-centered approaches. However, the traditional “chalk-and-talk” method still dominates many classrooms. Consequently, efforts to improve performance have shifted toward technology-supported strategies that make learning more interactive and meaningful. One such strategy is the use of computer simulations.

Computer simulations are interactive digital tools that allow learners to visualize and manipulate biological processes that may be difficult to observe in real life. Through animations, visual models, and immediate feedback, students can explore complex concepts such as cell division, reproduction, and genetic variation in dynamic and engaging ways. These tools are particularly beneficial in schools where laboratory facilities are limited, as they provide virtual experiments that replicate real-world conditions. Previous studies have demonstrated that simulation-based instruction improves students’ motivation, conceptual understanding, and academic performance (Gambari et al., 2013; Chen et al., 2017; Asogwa et al., 2016).

Globally, the integration of Information and Communication Technology (ICT) in education has become a key priority. Kenya’s education policies also emphasize the use of digital tools to enhance teaching and learning, especially in science subjects. Programs under the Ministry of Education and CEMASTE have encouraged teachers to incorporate technology into their lessons to promote inquiry-based and learner-centered learning. Despite these efforts, limited digital infrastructure and inadequate teacher training continue to hinder the effective implementation of computer-based learning in many public schools (Khan, Hasan & Clement, 2022).

In Kesses Sub-County of Uasin-Gishu County, Biology performance has remained low despite ongoing curriculum reforms and capacity-building

efforts. This situation calls for a closer examination of alternative instructional methods that can enhance understanding and improve students’ academic performance. Assessing the influence of computer simulations within this context can provide evidence-based insights for improving instructional practices and guiding curriculum development.

1.1 Research Objectives

The persistent low performance in Biology among secondary school students highlights the need for innovative and evidence-based instructional strategies. This study therefore sought to examine the influence of computer simulations on students’ academic performance in Biology in public secondary schools in Kesses Sub-County, Kenya.

1.2 Specific Objectives

1. To examine the effect of computer simulations on students’ academic performance in Biology.
2. To assess how computer simulations influence students’ understanding and retention of Biology concepts.
3. To compare the academic performance of students taught using computer simulations with those taught through conventional instructional methods.

1.3 Research Questions

1. What is the effect of computer simulations on students’ academic performance in Biology?
2. How do computer simulations enhance students’ understanding and retention of Biology concepts?
3. Is there a significant difference in academic performance between students taught using computer simulations and those taught through conventional methods?

1.4 Research Hypothesis

To address the objectives and questions, the following null hypothesis was tested:

H₀1: There is no statistically significant difference in students’ academic performance between those taught using computer simulations and those taught through conventional instructional methods

2. Literature Review

Globally, Biology is recognized as a key science that develops analytical and problem-solving skills essential for innovation and national development.

Despite its importance, student performance in Biology remains low due to the subject's abstract nature and reliance on traditional teacher-centred methods that discourage inquiry and participation (Eddy, Brownell, & Wenderoth, 2014; Osborne, 2023). Many students struggle to visualise complex processes such as genetics and reproduction, leading to poor understanding and low achievement.

To overcome these challenges, educators increasingly use computer simulations to enhance learning. Simulations present biological concepts through interactive visuals that allow learners to observe, experiment, and receive instant feedback, making abstract ideas concrete (Dahlgren, Huber, & McKinley, 2019). They promote active learning and align with constructivist theory, where students build their own understanding through exploration and reflection (Piaget, 1972; Suhendi, 2018). Studies consistently show that simulation-based instruction improves comprehension, motivation, and long-term retention (Chen, Wang, Yu, & Liu, 2017; Asogwa, Ude, & Diogu, 2016).

Across Africa, computer simulations are increasingly used as affordable alternatives to physical laboratories, especially where resources are limited. Research in Nigeria, Ghana, and South Africa reports improved academic performance and stronger motivation among students taught using simulations (Adebayo, Olalekan, & Oladele, 2016; Kibirige & Hodi, 2019). However, success depends on teacher competence and access to ICT resources, which remain limited in many schools (Dilshed, Tabassum, & Latif, 2016; Nelson & Johnson, 2021).

In Kenya, Biology continues to record poor results despite curriculum reforms and professional development initiatives such as SMASE through CEMASTE. Teacher-centred approaches still dominate, and abstract topics like genetics and reproduction remain difficult for learners (Obonyo, 2023; Orodho, 2022). The Kenya National Examination Council (2018) has reported that only a small proportion of candidates achieve satisfactory grades in Biology, pointing to a need for more engaging instructional strategies. Integrating computer simulations offers an opportunity to improve performance by providing virtual environments for experimentation and inquiry, especially in schools with limited laboratory facilities (Kibirige, Masha, & Seroto, 2021; Joyce, Mulinge, & Wambua, 2021).

Nevertheless, barriers such as inadequate ICT infrastructure, unreliable power, and insufficient teacher training continue to restrict the effective use of simulations (Gacheri & Ndiritu, 2021; Khan, Hasan, & Clement, 2022). Simulations should therefore complement rather than replace hands-on laboratory work to ensure students gain both conceptual understanding and practical skills (University at Buffalo, 2024).

Regardless of growing evidence on the potential of simulations, few studies in Kenya have examined their direct influence on academic performance, retention, and participation in Biology classrooms. In Kesses Sub-County, where performance remains low, this gap calls for focused research to determine how simulation-based teaching can improve learning outcomes. This study therefore investigates the influence of computer simulations on students' academic performance in Biology, contributing evidence to support more effective, technology-driven instruction in secondary schools.

3. Methodology

3.1 Study Area

The study was conducted in Kesses Sub-County within Uasin Gishu County, Kenya, a region known for its agricultural productivity and educational institutions. Eldoret is the county's capital and serves as the main urban and administrative hub. Uasin Gishu County comprises six sub-counties, with Kesses Sub-County comprising four wards and 39 public secondary schools. These schools were selected for the study due to persistently low performance in the Kenya Certificate of Secondary Education (KCSE) Biology examinations.

3.2 Research Design

The study adopted mixed method research design, with a quasi-experimental design, particularly the Solomon Four-Group Design, which is suitable for educational settings involving naturally existing groups. Additionally, a survey research design was applied. This design helped mitigate threats to internal validity such as maturation and testing effects. Four co-educational schools were randomly selected and allocated to control and experimental groups to evaluate the effects of the intervention - computer simulations - on Biology performance, see Table 1.

Table 1: Research Design Description

Group	Pre-Test	Treatment	Post-Test
Group I	O1	X	O2
Group II	O3	–	O4
Group III	–	X	O5
Group IV	–	–	O6

Group I: Received a pre-test (BAT1), followed by computer simulation-based instruction for four weeks, then a post-test (BAT2), and finally a retention test (BAT3) after two weeks.

Group II: Took a pre-test, underwent conventional teaching (chalk-and-talk/practical), then completed BAT2 and BAT3 for retention.

Group III: No pre-test was administered, teaching done via computer simulations, followed by BAT2 and BAT3.

Group IV: Conventional method of teaching was used, there was no pre-test administered, BAT2 was administered then BAT3.

Due to resource constraints, the researcher adopted existing online computer simulation models focusing on the topic "Reproduction in Human Beings" (including reproductive organs, Oogenesis, spermatogenesis, and menstrual cycle) instead of developing new ones. These simulations provided interactive and visual learning experiences to enhance student engagement and understanding.

3.3 Target Population

The study targeted all Form Three students and Biology teachers in the 39 public secondary schools in Kesses Sub-County, totaling approximately 1,755 students.

3.4 Sample Size and Sampling Techniques

Sampling was carried out using a combination of purposive for teachers of biology, simple random for intact classes, and stratified random techniques. Schools were first categorized by availability of computer facilities. From each category (extra county, county, and private), one school with and one without computers was randomly selected, prioritizing those with functional computer labs. Only schools that offered both Biology and Computer Studies were considered. Teachers of Biology in these schools were purposively included to ensure consistency in instructional quality. Form Three students in the sampled schools formed the core study group. The researcher randomly assigned 240 students into the four Solomon design groups to receive either computer-based or conventional instruction.

3.5 Research Instruments

The following instruments were used to collect data: Biology Achievement Tests (BAT1, BAT2, and BAT3): To assess academic performance and content

retention. Questionnaires: Administered to both students and teachers to gather data on participation in Biology Practical and perceptions of the learning experience. Observation Schedules: Used during lessons to assess learner engagement and teaching practices.

3.6 Methods of Data Analysis

The analysis involved both descriptive and inferential statistics: Descriptive statistics: Included frequencies, percentages, means, and standard deviations to summarize the data. Inferential statistics: Included t-tests, that is, paired sample t-test (Dependent t-test) and ANOVA. The t-test was used to compare pre-test and post-test scores between control and experimental groups, determining the statistical significance of differences in academic performance. The ANOVA test was applied to compare means across the four groups and assess the influence of content retention and learner participation on performance. Tables were used for clear data presentation.

4. Results and Discussion

4.1 Response Rate

The study targeted a sample of 478 Biology teachers and 240 Form Three students across selected public secondary schools in Kesses Sub-County. However, considering that only four Biology teachers had prior experience using computer simulations, it was deemed more appropriate to collect in-depth qualitative data from these specific individuals. Therefore, interview schedules were administered exclusively to the four teachers who had implemented computer simulations, in order to gain insights into their experiences, challenges, and perceived influence on instruction. On the other hand, quantitative data were collected using questionnaires from 120 Form Three students who were exposed to computer simulations (i.e., the experimental groups). These students provided responses regarding their engagement, content retention, and perceptions of the simulation-based instruction. Out of the targeted 240 students, complete data (pre-test, post-test, and questionnaires) were successfully collected from all 240, resulting in a 100% response rate for students. For teachers, valid responses were obtained from 473 out of 478, yielding a response rate of 98.95%. However, only data from the four teachers who used computer simulations were included in the qualitative analysis via interviews. Below is a discussion of the findings of the study.

4.2 Influence of Using Computer Simulations on Academic performance in Biology

H_{01} : There is no statistically significant relationship between computer simulations and academic

performance in public secondary schools in Kesses Sub-County, Kenya

Table 2: T-Test Results for H_{01} :

Statement	t-value	df	p-value
Computer simulations improve academic performance in Biology.	2.48	72	0.016

The t-value (2.48) is the test statistic from an independent samples t-test (likely comparing the post-test scores of students taught using computer simulations vs. those taught using traditional methods). This t-value indicates that there is a statistically significant difference between the means of the two groups. A positive t-value simply means that the mean score of the group taught with computer simulations was higher than the control group's mean score.

The p-value of 0.016 is less than the significance level of 0.05, indicating that there is a statistically significant relationship between computer simulations and learners' academic performance in Biology. Therefore, we reject H_{01} , meaning there is a statistically significant relationship between computer simulations and academic performance in Biology.

These results are strongly supported by numerous studies. Dahlgren et al. (2019) noted that computer simulations allow learners to visualize theoretical and real behaviors simultaneously, enhancing understanding and promoting better outcomes. Jeronen et al. (2016) emphasized that web-based simulations offer opportunities for students to conduct real-world experiments remotely, which improves their learning experience. Helikar et al. (2015) observed that interactive simulations led to greater learner engagement and improved academic performance, while Elongavan (2017) demonstrated that students taught with realistic simulations had fewer misconceptions and higher achievement scores. Similarly, Cook et al. (2012) argued that although simulations are beneficial, they should not entirely replace traditional labs in hands-on disciplines. Weltman et al. (2019) supported this view, stressing that physical manipulation is critical in skill development and suggesting that simulations work best as complementary tools.

In the African context, Asogwa et al. (2016) found that simulations were more effective than traditional instruction methods, especially in fostering conceptual understanding and student motivation. Dilshed, Tabassum, and Latif (2016), though highlighting the advantages of digital instruction in African schools, noted that a lack of adequate teacher training limits the full realization of simulation-based learning. The study

stressed the need for continuous professional development to enable teachers to integrate simulations effectively into their pedagogy.

Kenyan-based studies echo similar sentiments. Kibirige et al. (2021) and Alfajam et al. (2021) confirmed superior academic performance among students taught using simulations in Biology, affirming the potential of digital tools to enhance learning outcomes. However, concerns persist. Shudayfat et al. (2023) reported that many Kenyan science educators still face challenges in leveraging simulations due to insufficient ICT competence and limited access to resources. These limitations may reduce the potential influence of simulations on student learning, particularly in under-resourced public secondary schools.

The implications of this study's findings for education are significant. First, the demonstrated effectiveness of computer simulations should prompt curriculum developers, such as the Kenya Institute of Curriculum Development (KICD), to integrate these tools systematically into Biology syllabi. Secondly, teacher training programs must incorporate digital pedagogy to equip educators with the skills to use simulation software effectively. Additionally, educational policymakers and school administrators should invest in digital infrastructure and provide support for simulation-based learning environments.

5. Conclusion and Recommendations

5.1 Conclusions

The use of computer simulations has a statistically significant positive effect on learners' academic performance in Biology. This led to the rejection of the null hypothesis (H_0), indicating a meaningful relationship between the use of simulations and improved academic outcomes. Students taught using computer simulations outperformed those taught using traditional methods such as chalk-and-talk and physical practical. This suggests that simulations enhance content understanding, retention, and student engagement. These findings align with constructivist

theory, which emphasizes interactive learning as a means of constructing knowledge. Despite this, the study also acknowledges limitations associated with simulation use, such as teacher preparedness, inadequate ICT infrastructure, and the need for a balanced approach that includes hands-on practical experiences. Therefore, while computer simulations are beneficial, they should complement rather than replace traditional teaching methods.

5.2 Recommendations

The study recommends the following:

1. **The Kenya Institute of Curriculum Development (KICD) should officially integrate computer simulations** into the secondary school Biology curriculum, particularly on abstract topics that learners find difficult. Simulations can make invisible processes visible, and help learners 'see' what is normally just imagined
2. **Schools should deliberately invest in simulations tools** as a strategy to lift Biology performance. Administrators should not treat this as optional; simulations have shown measurable impact and can therefore become part of school quality-improvement plans.
3. **Teachers should have in-service professional development** on how to select, plan, and implement simulations effectively. This includes training on how to blend digital activities with questioning techniques, guided discovery, and inquiry-based tasks.
4. **Students should have structured access to simulations** beyond teacher lesson time. For example, schools can timetable weekly open-lab sessions to what they saw in class. The extra exposure improves retention.
5. **The Ministry of Education, in collaboration with stakeholders and NGOs** should invest in adequate ICT infrastructure in public schools by ensuring stable electricity, internet access, and computers. Simulations cannot work well if the basic digital environment is poor.
6. **Schools should adopt a blended approach** that uses both computer simulations and hands-on practical. This will ensure students gain both conceptual understanding and real scientific skills. When combined learners get the best of both worlds.

References

- Abrandt Dahlgren, M., Rystedt, H., Felländer-Tsai, L., & Nyström, S. (2019). Simulation in Health Care: Materiality, Embodiment, Interaction.
- Adebayo, O. O., Olalekan, O. J., & Oladele, K. A. (2016). Effects of computer simulation on Students' performance in biology. *International Journal of Education and Research* 3(9), 45–54.
- Alfajam, O., Kimani, P., Mwangi, J. (2021). Effects of digital simulations on students' performance in science subjects in Kenyan secondary schools. *African Journal of educational Research and Development* 13(2), 78-90.
- Aswoga, U.D., Ude, I.d., & Diogu, J.O. (2016). Effects of computer simulations on students' achievement in Biology in secondary schools in Nigeria. *International Journal of Education and Evaluation*, 2(6), 1-8.
- Chen, Z., Wang, Y., Yu, G., & Liu, X. (2017). Using simulations to promote learning in biology: Effects on academic performance and student engagement. *Journal of Educational Computing Research*, 55(8), 1158–1175.
- Cook, D. A., Hamstra, S. J., Brydges, R., Zendejas, B., Szostek, J. H., Wang, A. T., ... & Hatala, R. (2012). Comparative effectiveness of instructional design features in simulation-based education: systematic review and meta-analysis. *Medical teacher*, 35(1), e867-e898
- Dahlgren, P., Huber, M., & McKinley, M. (2019). Using computer simulations to enhance biology education. *Journal of Biological Education*, 53(2), 122–131. <https://doi.org/10.1080/00219266.2018.1492293>.
- Dankbaar, M. E., Alsmas, J., Jansen, E. E., van Merriënboer, J. J., van Saase, J. L., & Schuit, S. C. (2016). An experimental study on the effects of a simulation game on students' clinical cognitive skills and motivation. *Advances in Health Sciences Education*, 21(3), 505-521.
- Darwish, S., & Hamad, M. (2021). Transforming science teaching through virtual simulations: A systematic review. *International Journal of Instructional Technology and Distance Learning*, 18(5), 13–28.
- Dilshad, M., Malik, R. A., Tabassum, R., & Latif, M. I. (2016). Impact of Computer Simulation on the Achievement of Biology Students at Secondary Level. *Pakistan Journal of Social Sciences (PJSS)*, 36(2).
- Dilshad, N., Tabassum, F., & Latif, S. (2016). Barriers to effective ICT integration in science classrooms. *Journal of Educational Technology*, 13(4), 67–76
- Eddy, S. L., Brownell, S. E., & Wenderoth, M. P. (2014). Gender gaps in achievement and participation in biology classrooms. *CBE—Life Sciences Education*, 13(3), 478–492. <https://doi.org/10.1187/cbe.13-10-0204>

- Elongavan, R. (2017). Effectiveness of simulation-based teaching on biology achievement. *International Journal of Educational Research and Technology*, 8(2), 52–59.
- Ezeaghasi, N., Obochi, N., & Odechukwu, F. (2018). Simulation models and cognitive retention in biology instruction. *Journal of Science Education Research*, 6(2), 13–22.
- Gacheri, C. M., & Ndiritu, L. M. (2021). Barriers to the use of computer simulations in teaching biology in Kenyan secondary schools. *Journal of Educational Technology and Curriculum Studies*, 9(2), 33–41.
- Gambari, A. I., Yaki, A. A., & Olowe, M. B. (2013). Enhancing secondary school students' achievement and retention in biology through computer-assisted instruction. *International Journal of Modern Education and Computer Science*, 5(6), 26–34.
- Helikar, T., Cutucache, C. E., Dahlquist, L. M., Herek, T. A., Larson, J. J., & Rogers, J. A. (2015). Integrating Interactive computational modeling in biology curricula. *PLOS computational biology*, 11(3), e1004131.
- Jeronen, E., Palmberg, I., & Yli-Panula, E. (2016). Teaching methods in biology education and sustainability education including outdoor education for promoting sustainability—a literature review. *Education Sciences*, 6(3), 24. <https://doi.org/10.3390/educsci6030024>.
- Joyce, K., Mulinge, M., & Wambua, E. (2021). Simulation and demonstration methods: Effect on science achievement. *Kenya Journal of Education Planning Economics and Management*, 13(2), 90–101.
- Kenya National Examination Council (KNEC). (2018). Report on candidates' performance in biology. Nairobi: KNEC.
- Khan, A., Hasan, M., & Clement, M. (2022). Infrastructure and resource challenges in implementing ICT in developing countries. *Technology in Society*, 68, 101851. <https://doi.org/10.1016/j.techsoc.2021.101851>.
- Kibirige, I., & Bodirwa, K. B. (2021). The Effect of Using Computer Simulations on Grade 11 Learners' Performance in Plants Biodiversity in South Africa. *Journal of Baltic Science Education*, 20(4), 612–621.
- Kibirige, I., & Hodi, K. S. (2019). Effects of simulation on students' achievement and motivation in science. *South African Journal of Education*, 39(2), 1–9.
- Kibirige, I., Masha, K., & Seroto, J. (2021). Comparative study of simulation and lecture methods on academic performance in biology. *African Journal of Research in Mathematics, Science and Technology Education*, 25(1), 56–67.
- Nelson, M., & JOHNSON, R. (2021). ICT Integration and Teacher competence in Sub-Saharan African Schools: Challenges and prospects. *African Journal of Education and Technology*, 11(3), 45–57.
- Nkirete, J. M., & Thinguri, R. (2020). Role of science practicals in students' acquisition of laboratory skills in Kenya. *International Journal of Educational Policy Research and Review*, 7(3), 66–75.
- Obonyo, S. A. (2023). Enhancing student achievement in Biology. The role of innovative instructional strategies in Kenya. *African Journal of Science Education*, 3(2), 112–124.
- Joyce, K., Mulinge, M., & Wambua, E. (2021). Simulation and demonstration methods: Effect on science achievement. *Kenya Journal of Education Planning Economics and Management*, 13(2), 90–101.
- Obonyo, S. A. (2023). Enhancing student achievement in biology: The role of innovative instructional strategies in Kenya. *African Journal of Science Education*, 3(2), 112–124.
- Orodho, J. A. (2022). Curriculum implementation challenges in teaching biology in Kenyan secondary schools. *Kenya Journal of Education Planning, Economics and Management*, 14(1), 45–56.
- Osborne, J. (2023). Science education for the twenty-first century learner. *Science Education*, 107(2), 377–395.
- Piaget, J. (1972). *The psychology of the child*. Basic Books.
- Rehman, N., Zhang, W., Mahmood, A., & Alam, F. (2021). Teaching physics with interactive computer simulation at secondary level. *Cadernos de Educação Tecnologia e Sociedade*, 14(1), 127–141.
- Shudayfat, E. A., Alazaidah, R., Aljaidi, M., Yusoff, M., Al-Safarini, M. Y., & Alidmat, O. (2023, December). Human-computer interaction in augmented reality: Applications and challenges. In *2023 2nd International Engineering Conference on Electrical, Energy, and Artificial Intelligence (EICEEAI)* (pp. 1–6). IEEE.
- Srivastava, D., Kumari, A., & Gond, P. K. (2020). Promoting inquiry-based learning in biology through digital tools. *International Journal of Science and Research*, 9(5), 165–171.
- Suhendi, E. (2018). Constructivist approach to teaching and learning in science. *International Journal of Educational Research*, 4(2), 50–58.

University at Buffalo. (2024). Balancing virtual and hands-on learning in science classrooms. Buffalo, NY: Center for Teaching Innovation.

Vieira, R. M., & Tenreiro-Vieira, C. (2016). Fostering scientific literacy and critical thinking in science education. *International Journal of*

Science and Mathematics Education, 14(4), 659–680.

Weltman, D., & Tokar, T. (2019). Using a Monte Carlo simulation exercise to teach principles of distribution: An enhanced version of the classic transportation problem. *INFORMS Transactions on Education*, 19(3), 111-120.