Role Play as an Effective Engagement Technique in an Introductory Biology Class

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ABSTRACT

Protein translation is a fundamental biological process taught in introductory general biology classes at the undergraduate level. This core scientific topic is often hard for students to understand as it involves several key players and piecing together of information learned in multiple lectures. The current study examines the effectiveness of role play as a complementary pedagogical tool for promoting student understanding, retention, and recall of the basic mechanics of protein translation. Students in 2 different sections of the same undergraduate biology class were involved in this investigation. In this active learning strategy, students assumed the roles of the various components involved in translation including the ribosome binding site, mRNA codons, polyA tail, tRNAs, and ribosome and then enacted the role play in class after a traditional lecture. Both pre-role play and post-role play assessments were used to gauge student comprehension of translation and hence determine the effectiveness of role play. Results from the quantitative analysis of data supported the hypothesis and revealed a statistically significant increase in mean student scores post role play in both sections. This study reiterates the importance of collaborative learning in student engagement and learning outcomes.

INTRODUCTION

The introductory general biology course at the Community College of Baltimore County (CCBC) is titled Molecules and Cells (BIOL 110) and it is the foundational course for students who intend to take more advanced courses such as anatomy and physiology or microbiology. CCBC's BIOL 110 is a very challenging course covering a wide range of topics from basic chemistry and cellular biology, metabolism, to complex topics in genetics and molecular biology. Part of the reason this is a very challenging course is due to the diversity in the levels of readiness of the students we serve. Many of our students are first-generation college students, students coming back to college after several years (or decades), students who were home schooled, students who are looking for a change in career, students working multiple jobs with family and work commitments, and everybody in between. In such a setting, instructors need to be adaptable and constantly update their arsenal of teaching strategies.

The main goal of any instructor is to prepare students to achieve their learning goals successfully. Often, the time-tested traditional lecture-based teaching method can reduce the student experience to passive consumption of information. Numerous scholastic studies have recognized the benefits of active learning strategies on student learning outcomes (Freeman et al., 2014; Hake, 1998; Michael, 2006; Prince, 2004; Rossi et al., 2021). In addition, pedagogical research has reiterated that active learning methods complement the traditional lecture-based methods to foster deep comprehension among the diverse types of learners including visual, auditory, read/write, and kinesthetic (Bromley, 2013; Minhas et al., 2012). Finally, active learning methods have been shown to reduce disparities in learning and improve equity in the classroom (Burke et al., 2020; Eddy & Hogan, 2014; Kressler & Kressler, 2020; Theobald et al., 2020).

Although there are several student engagement techniques involving active learning (Barkley & Major, 2020), role play was implemented in the current study as an intervention to stimulate higher-order cognitive abilities and address student engagement. Role play is an innovative, hands-on, collaborative activity that enables students to assume different identities or roles and enact according to an imagined circumstance in a classroom setting (Barkley & Major, 2020). By engaging students in a collaborative situation, role play can transform an abstract biological process/concept into a tangible and relatable experience.

Role playing has been implemented to teach several biological concepts including the electron transport chain (Harrison, 2020), endocrine regulation (Hudson, 2012), bacterial gene regulation (Sampath, 2023), mitosis (Wyn & Stegink, 2000), diffusion across cell membranes (Harrison, 2018), glycolysis and the Krebs cycle (Saab & Shaaban, 2022; Ross et al., 2008), transcription and translation (Sturges et al., 2009), the central dogma of molecular biology (Takemura & Kurabayashi, 2014) and more. Role play has been employed in different fields including biology, anatomy and physiology microbiology, nursing, and medicine (Church, 2021). Many of these instances were associated with positive learning outcomes.

Protein translation is a complex process fundamental to the understanding of cell function. It involves the participation of several components to synthesize a protein based on a specific mRNA template (Campbell et al., 2021). However, the intangible nature of this mechanism poses a challenge to many undergraduate students resulting in a lack of engagement and hence lack of deeper understanding. It is important that students in foundational courses like BIOL 110 gain a solid knowledge of this complex mechanism because they would need to apply this knowledge when they learn about antibiotics in the higher-level microbiology course, for example. So, the rationale for using role play to complement a traditional lecture on protein translation is to involve students in reconstructing the molecular interactions during translation and hence facilitate the deeper understanding of complex concepts and support collaborative learning and critical thinking.

The aim of the current study was to investigate the effect of role play on student-understanding of protein translation. The hypothesis of this classroom investigation was that role play can significantly improve student knowledge of the mechanistic details and functional significance of this essential biological process. To evaluate this, quantitative assessment was used to gauge cognitive learning. Subsequent analysis of the results showed that average student scores improved significantly, and the standard deviation reduced after role play. This study adds to the mounting evidence supporting active learning in science education and offers a practical idea for educators to improve student comprehension and engagement in a molecular biology course, especially in a class where there is diversity in student preparedness as in a community college classroom.

METHODS

Traditional Lecture

Students from 2 different undergraduate sections of BIOL 110 at CCBC were involved in protein translation role play in the classroom. Section 1 had 16 students, 11 of whom were registered to go to nursing and other allied health fields. Section 2 had 12 students, 10 of whom were registered to go to nursing and other allied health fields. BIOL 110 is a pre-requisite for students to take higher-level anatomy and physiology as well as microbiology classes before they enter nursing and other allied health fields. So, these students need a strong foundation in general biology.

The students were given a traditional lecture on the process of translation during the scheduled class period. Prior to the traditional lecture, students had taken a quiz based on the assigned chapter reading in order to get familiar with the study material. In addition, students were also given a PowerPoint deck of the lecture topic and a list of vocabulary words with definitions before the lecture. The students were also given guided skeletal notes to use during the lecture. The entire class worked together on concept mapping at the end of the lecture to review the concepts. After the lecture, the students were provided with a study guide.

Pre-Role Play Assessment

Following the traditional lecture and related activities, each student was given a 5-minute, 5-question, multiple choice, closed-book quiz worth 5 total points. The quiz questions were about the location and mechanism of translation (Figure 1). The questions used in this assessment were different from the chapter pre-quiz that they had already taken.

BIOL 110 **Protein Translation Quiz** **Dr. Avadhani**

1. The cellular structure responsible for translation is ____________.

   A. Nucleus
   B. Ribosome
   C. Golgi apparatus
   D. Cell membrane

2. Protein translation takes place in the ___________ in eukaryotes and __________ in prokaryotes.

   A. Nucleus; cytoplasm
   B. Cytoplasm; Nucleus
   C. Nucleus; Nucleus
   D. Cytoplasm; Cytoplasm

3. Please select the correct statement.

   A. mRNA binds to the amino acid as well as tRNA.
   B. tRNA binds only to the amino acid.
   C. tRNA binds to the amino acid as well as mRNA.
   D. mRNA binds directly to the amino acid.

4. The process of translation always begins at the ______________ on the mRNA molecule.

   A. Promoter
   B. Start codon
   C. Exon
   D. PolyA tail

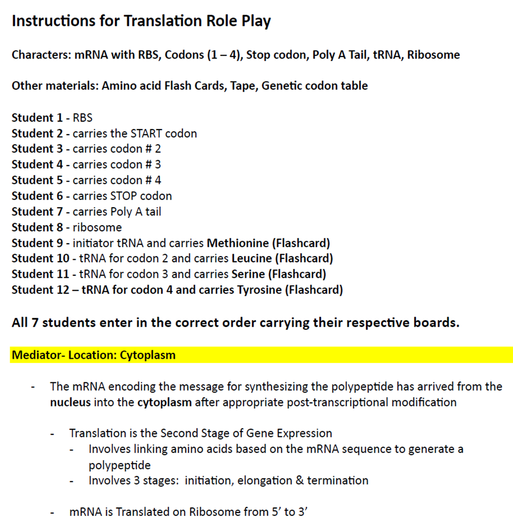
5. Which of the following statements is true?

   A. The anticodon is present on only on tRNA, while the codon is present only on mRNA.
   B. The anticodon is present on mRNA, while the codon is present on tRNA.
   C. The anticodon is present on rRNA, while the codon is present on tRNA.
   D. The anticodon and the codon are present on all types of RNA.

Figure 1. The questions used for the pre- and post-role play quizzes.

Role Play

Following the traditional lecture, instructions for role play were given to students via Brightspace, the learning management system used at CCBC (Figure 2). A set of 12 role play cards were color printed on 8.5″ x 11″, 67# White Vellum Bristol at a font size of 32 – 239 (Figure 3). Roles were self-assigned by the students. Each card/student represented the following: ribosome binding site (Student 1), start codon (Student 2), codons 2 – 4 (Students 3, 4, and 5), stop codon (Student 6), polyA tail (Student 7), ribosome (Student 8), initiator tRNA (Student 9), and the tRNAs carrying amino acids corresponding to codons 2 – 4 (Students 10, 11, and 12). The respective amino acids were denoted on different flash cards (3″ x 5″) and the students representing the tRNAs carried their respective amino acid flash cards.



Instructions for Translation Role Play

Characters: mRNA with RBS, Codons (1 – 4), Stop codon, Poly A Tail, tRNA, Ribosome

Other materials: Amino acid Flash Cards, Tape, Genetic codon table

Student 1 - RBS
Student 2 - carries the START codon
Student 3 - carries codon # 2
Student 4 - carries codon # 3
Student 5 - carries codon # 4
Student 6 - carries STOP codon
Student 7 - carries Poly A tail
Student 8 - ribosome
Student 9 - initiator tRNA and carries **Methionine (Flashcard)**
Student 10 - tRNA for codon 2 and carries **Leucine (Flashcard)**
Student 11 - tRNA for codon 3 and carries **Serine (Flashcard)**
Student 12 – tRNA for codon 4 and carries Tyrosine (Flashcard)

All 7 students enter in the correct order carrying their respective boards.

Mediator- Location: Cytoplasm

- The mRNA encoding the message for synthesizing the polypeptide has arrived from the **nucleus** into the **cytoplasm** after appropriate post-transcriptional modification
  - Translation is the Second Stage of Gene Expression
    - Involves linking amino acids based on the mRNA sequence to generate a polypeptide
    - Involves 3 stages: initiation, elongation & termination
  - mRNA is Translated on Ribosome from 5′ to 3′

Figure 2. A sample of some of the instructions provided to the students about the role play activity in Brightspace.

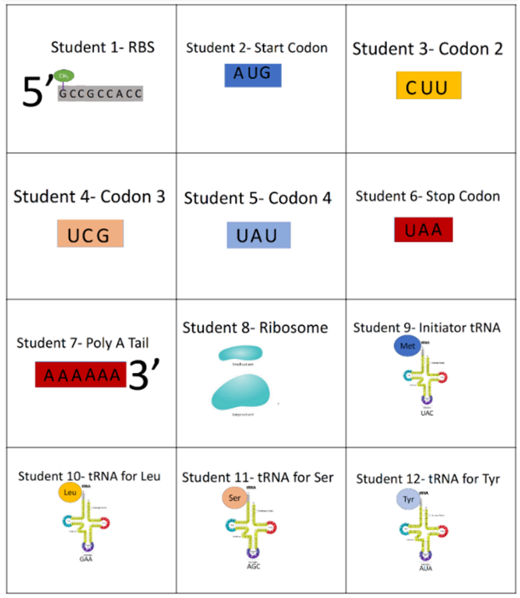


Figure 3. The 12 role play cards selected and enacted by the students.

The printed cards were given to the students on the day of role play enactment. Role play was carried out in the classroom a week after the traditional lecture so that the students would have some time to practice their roles. During the enactment, students held out their respective cards for the audience/non-role playing students to see. The students in the audience were given a printed copy of the codon table with codons and their corresponding amino acids so they could be involved in the role play as well. The instructor acted as the moderator in conducting the role play. Each student performed their role as the moderator announced their entry and exit.

The role play began with the ribosome and the initiator tRNA binding to the start codon and continued with the ribosome moving sequentially from one codon to the next. The students representing tRNAs carried their respective amino acids. The exiting student tRNA handed their amino acid/flash card to the incoming student tRNA connecting the amino acids/flash cards using a piece of scotch tape. The role play concluded when the ribosome reached the stop codon, when student 12 placed the glued flash cards on the table, representing the finished product.

Post-Role Play Assessment

The effectiveness of role play in student engagement and comprehension of the process of translation was assessed by using a post-role play quiz. Immediately following role play, each student was given a 5-minute, 5-question, multiple choice, closed-book quiz worth 5 total points based on the location and the mechanism of translation. The questions used in this assessment were different from the chapter pre-quiz that they had already taken but were the same as those used in the pre-role play quiz (Figure 1).

Long-term retention and recall of the process of translation was determined using the same assessment questions approximately 5 weeks after the role play intervention for section 1 and 3 weeks after the role play intervention for section 2. The difference in the time between the sections is due to section 2 being an accelerated 10-week section running on a slightly different schedule.

Statistical analysis of the data was performed using Microsoft Excel.

RESULTS

A quantitative study was used to assess the effect of role play on student understanding of protein translation. Pre-role play and post-role play assessments were designed to evaluate the comprehension and retention of the mechanism of protein translation by students. Overall, the mean quiz scores for both sections increased post-role play. The class results from each section are discussed below.

Section 1

As indicated in Table 1 and Figure 4, the mean quiz scores increased from 67.5% before role play to 78.75% after role play. 37.5% of the students (6/16) showed no change in scores, while 43.75% (7/16) students showed an increase in quiz scores. There was a small drop in the scores of the remaining 18.75% students (3/16). Among the sub-set that showed an increase in mean quiz scores, the quiz scores increased from 37% pre-roleplay to 71.4% post-roleplay (1.85/5 to 3.57/5). In addition, the standard deviation decreased between the pre- and post-role play quiz scores. The p-value was calculated to be 0.00865.

Table 1. Mean Student Scores on the Pre- and Post-Role Play Assessments.		
	Section 1	**Section 2**
Pre-role play	3.375 ± 1.65 (67.5%)	2.166 ± 1.81 (43%)
Post-role play 1 (short-term retention)	3.9375 ± 0.89 (78.75%)	3.25 ± 1.16 (65%)
Post-role play 2 (long-term retention)	3.4375 ± 1.36 (68.75%)	3.00 ± 1.35 (60%)

Figure 4. Comparison of student scores (n = 16) before and after role play in section 1. Bars 1 – 16 represent individual students and bar 17 represents the class mean. Post-role play 1 was administered immediately after the role play intervention to test short-term retention and recall; post-role play 2 was administered 5 weeks after the role play intervention to test long-term retention and recall.

Long-term retention and recall (post-role play) of the process of translation determined using the same assessment revealed a class mean of 68.75% (3.4375/5), with 56.25% (9/16) of students showing either the same or an increase in score from post role play (Figure 4). The p-value was calculated to be 0.00016265 with respect to the pre-role play assessment and 0.01913523 with respect to the post-role play assessment.

Section 2

As indicated in Figure 5 and Table 1, the mean quiz scores increased from 43% prior to role play intervention to 65% after role play. 25% of students (3/12) showed no change in scores, while 66.66% of students (8/12) showed an increase in quiz scores. There was a small drop in the score of the remaining 8.3% students (1/16). Among the sub-set that showed an increase in mean quiz scores, the quiz scores increased from 20% pre-role play to 55% post-role play (1/5 to 2.75/5). In addition, the standard deviation decreased between the pre- and post-role play quiz scores. The p-value was calculated to be 0.01310745.

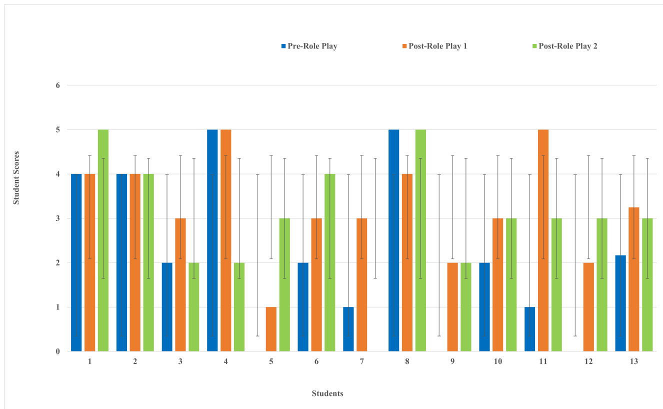


Figure 5. Comparison of student scores (n = 12) before and after role play in section 2. Bars 1 – 12 represent individual students and bar 13 represents the class mean. Post-role play 1 was administered immediately after the role play intervention to test short-term retention and recall; post-role play 2 was administered 3 weeks after the role play intervention to test long-term retention and recall.

Long-term retention and recall of the process of translation was determined using the same assessment and revealed a class mean of 60% (3/5), with 50% (8/16) of students showing either the same or an increase in scores after role play (Figure 5). The p-value was calculated to be 0.2268 with respect to the pre-role play assessment and 0.6763 with respect to the post-role play assessment.

In addition to the quantitative analysis described above, qualitative student feedback was collected via verbal survey and group discussion. The overall class response was very positive, and students reported being more engaged during the role play activity. They also mentioned that this interactive and collaborative activity was very enjoyable and made the abstract cellular process very relatable.

DISCUSSION AND CONCLUSION

The results of the current study involving 2 sections of BIOL 110 at CCBC suggest role play is an effective tool to complement traditional lecture and improve student engagement and understanding of complex topics like protein translation. The mean post-role play quiz scores from both sections increased significantly, implying that the improvement in scores was not due to random chance. The decrease in standard deviation between the pre- and post-role play quiz scores further strengthens this conclusion suggesting less variability and more precision.

Equally striking is the dramatic improvement in the mean post-role play quiz scores of 43.75% of students in section 1 and 66.6% of students in section 2. In fact, the mean scores for this group increased by a whopping 93% for section 1 and 175% for section 2. It also bears emphasizing that several students in this group scored 20% or less on the pre-role play quiz. A second group of students showed a small drop in their quiz scores, which may be attributed to the students misreading the questions, as generally these students do above average in the class otherwise. A third group of students showed neither an increase nor decrease in their post-role play scores (most of them were high scorers), implying that role play did not add to the resources they already had. Overall the increase in mean quiz scores, specifically the scores of students that had low scores prior to role play intervention, suggests that role play effectively improved student understanding of protein translation. Specifically, the students demonstrated improvement in understanding of the location and the mechanism of translation, including the roles of ribosome, and the different types of RNA molecules.

Regarding the effect of role play in long-term retention and recall, the results show that there was a drop in the mean class scores in the assessment given 3-5 weeks post-role play compared to the assessment given immediately after role play in both sections. However, these scores are still higher than the pre-role play assessment scores. While it is very tempting to make a strong case for role play, the p values from Section 2 for the long-term retention and recall (after role play) do not support this conclusion, in spite of showing a statistically significant score for short-term retention and recall.

The current study has very encouraging quantitative data and positive student feedback. Taken together, these data clearly support the hypothesis that role play is an effective pedagogical tool to promote student understanding, retention, and recall of information in the short term. However, for longer term retention and recall this strategy may not always be successful. A control where the role play assessment questions were given to students at the same time intervals as the current study, i.e. immediately after, 1 week after, and 3-5 weeks after the traditional lecture in the absence of role play would have added more credence to the data. However, the author is philosophically against using students as controls where a certain set of students is not given the same resources as the experimental group that could be beneficial. A good alternative would be to use the pre-role play quiz data from another instructor's class where role play has not been implemented.

Looking at the literature, one previous study implemented role play about protein synthesis including transcription and translation (Sturges et al., 2009), however there were some differences from the current study. First, their study involved a very large section (n = 298) in an anatomy and physiology class in a 4-year institution. The authors evaluated the effectiveness of role play based on student demographics, understanding, engagement, and satisfaction survey in addition to a pretest and posttest. Unlike the current study, student performance in the pretest and posttest was not analyzed at a granular level.

Another study documented the use of role play to teach the central dogma of molecular biology (Takemura & Kurabayashi, 2014). Translation was only part of the process that was enacted, while the current study focused exclusively on translation. In addition, the target audience was a small group (n = 15) of students at a Japanese university whose primary subject of study was mathematics, physics, and chemistry, not biology. In their study student interest in the topic was assessed using a survey but student performance data were not presented.

Future research should explore the long-term retention of knowledge, the applicability of role play to teach multiple concepts throughout the semester, and its effects across multiple semesters. Role play can be easily adapted to teach several other core concepts in general biology classes such as cellular respiration, DNA structure and replication, RNA transcription, cell division, and more. Another consideration could be videotaping the role play process and making it available for students to watch. With the availability of 3-D printing technologies, molecular models could be used in the place of paper boards to perform role play. Although role playing requires some planning, it is easy to implement, and allows students to be fully engaged in the classroom and comprehend intangible molecular processes.

Overall, this study found that group role play is a great way to engage students in collaborative learning and is a useful strategy in the teaching of fundamental scientific concepts at the undergraduate level. Role play also fosters soft skills like interpersonal communication, adaptability, problem solving abilities, and critical thinking to name a few. The results from the current study make a strong case for the use of role play as an active learning strategy in science education and demonstrates a hands-on strategy for educators to enhance student comprehension and engagement in molecular biology courses. This is invaluable in a class where there is diversity in terms of student readiness such as in a community college classroom. Providing a variety of resources to different types of learners improves equity

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REFERENCES

1. Barkley, E. F., & Major, C. H. (2020). Role Play. In Student Engagement Techniques (2nd ed., pp. 234–240). Jossey-Bass.
2. Bromley, P. (2013). Active learning strategies for diverse learning styles: Simulations are only one method. PS: Political Science & Politics, 46(4), 818–822. https://doi.org/10.1017/s1049096513001145
3. Burke, C., Luu, R., Lai, A., Hsiao, V., Cheung, E., Tamashiro, D., & Ashcroft, J. (2020). Making STEM equitable: An active learning approach to closing the achievement gap. International Journal on Active Learning, 5(2):71–85.
4. Campbell, N. A., Urry, L., Cain, M. L., Wasserman, S. A., Minorsky, P. V., & Orr, R. (2021). Gene expression: From gene to protein. In

Biology (12th ed.). Pearson.
5. Church, F. C. (2021). Active learning: Basic science workshops, clinical science cases, and medical role-playing in an undergraduate biology course. Education Sciences, 11(8), 370. https://doi.org/10.3390/educsci11080370
6. Eddy, S. L., & Hogan, K. A. (2014). Getting under the hood: How and for whom does increasing course structure work? CBE—Life Sciences Education, 13(3), 453–468https://doi.org/10.1187/cbe.14-03-0050
7. Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and Mathematics. Proceedings of the National Academy of Sciences, 111(23), 8410–8415. https://doi.org/10.1073/pnas.1319030111
8. Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. American Journal of Physics, 66(1), 64–74https://doi.org/10.1119/1.18809
9. Harrison, E. (2018). Role-playing activity to demonstrate diffusion across a cell membrane. Journal of Microbiology & Biology Education, 19(2). https://doi.org/10.1128/jmbe.v19i2.1576
10. Harrison, E. (2020). Role-playing activity to demonstrate the electron transport chain. The American Biology Teacher, 82(5), 338–340. https://doi.org/10.1525/abt.2020.82.5.338
11. Hudson, M. L. (2012). Easy, cheap, & fun: Role-play on endocrine regulation & negative feedback. The American Biology Teacher, 74(9), 644–646.https://doi.org/10.1525/abt.2012.74.9.8
12. Kressler, B., & Kressler, J. (2020). Diverse student perceptions of active learning in a large enrollment stem course. Journal of the Scholarship of Teaching and Learning, 20(1). https://doi.org/10.14434/josotl.v20i1.24688
13. Michael, J. (2006). Where's the evidence that active learning works? Advances in Physiology Education, 30(4), 159–167. https://doi.org/10.1152/advan.00053.2006
14. Minhas, P. S., Ghosh, A., & Swanzy, L. (2012). The effects of passive and active learning on student preference and performance in an undergraduate basic science course. Anatomical Sciences Education, 5(4), 200–207. https://doi.org/10.1002/ase.1274
15. Prince, M. (2004). Does active learning work? A review of the research. Journal of Engineering Education, 93(3), 223–231. https://doi.org/10.1002/j.2168-9830.2004.tb00809.x

16. Ross, P. M., Tronson, D. A., & Ritchie, R. J. (2008). Increasing conceptual understanding of glycolysis & the Krebs cycle using role-play. The American Biology Teacher, 70(3), 163–168. https://doi.org/10.2307/30163230
17. Rossi, I. V., de Lima, J. D., Sabatke, B., Nunes, M. A., Ramirez, G. E., & Ramirez, M. I. (2021). Active learning tools improve the learning outcomes, scientific attitude, and critical thinking in higher education: Experiences in an online course during the COVID-19 pandemic. Biochemistry and Molecular Biology Education, 49(6), 888–903. https://doi.org/10.1002/bmb.21574
18. Saab, M., & Shaaban, E. (2022). The impact of modeling and role play on grade eleven students' achievement and motivation while teaching Krebs Cycle in biology. International Journal of Research in Education and Science, 8(2), 219–242. https://doi.org/10.46328/ijres.2692
19. Sampath, V. (2023). Use of a role-playing activity to increase student understanding of bacterial gene regulation. Journal of Microbiology & Biology Education, 24(1).https://doi.org/10.1128/jmbe.00006-23
20. Sturges, D., Maurer, T. W., & Cole, O. (2009). Understanding protein synthesis: A role-play approach in large undergraduate human anatomy and physiology classes. Advances in Physiology Education, 33(2), 103–110. https://doi.org/10.1152/advan.00004.2009
21. Takemura, M., & Kurabayashi, M. (2014). Using analogy role-play activity in an undergraduate biology classroom to show Central Dogma Revision. Biochemistry and Molecular Biology Education, 42(4), 351–356. https://doi.org/10.1002/bmb.20803
22. Theobald, E. J., Hill, M. J., Tran, E., Agrawal, S., Arroyo, E. N., Behling, S., Chambwe, N., Cintrón, D. L., Cooper, J. D., Dunster, G., Grummer, J. A., Hennessey, K., Hsiao, J., Iranon, N., Jones, L., Jordt, H., Keller, M., Lacey, M. E., Littlefield, C. E., … Freeman, S. (2020). Active learning narrows achievement gaps for underrepresented students in undergraduate science, Technology, engineering, and math. Proceedings of the National Academy of Sciences, 117(12), 6476–6483. https://doi.org/10.1073/pnas.1916903117
23. Wyn, M. A., & Stegink, S. J. (2000). Role-playing mitosis. The American Biology Teacher, 62(5), 378–381. https://doi.org/10.2307/4450924