Enhancing Biotechnology Education through BioVate Competition: Increasing Conceptual Understanding and Science Communication in Science Education

Septi Kurniasih*
Science Education Department, Faculty of Teacher Training and Education, Universitas Sultan Ageng Tirtayasa
*Email: kurniasepti@untirta.ac.id

DOI: https://doi.org/10.33369/pendipa.9.1.111-117

ABSTRACT
The goal of this study was to explore the effectiveness of implementing competition during a learning process to elevate motivation and science communication skills in a particular biotechnology education course among the third-year science education students at Universitas Sultan Ageng Tirtayasa using the BioVate competition, in which incorporates project-based learning (PjBL) within competitions during learning process. It is a unique model for competitive learning. A quasi-experimental model was employed on a sample comprising 67 undergraduate students. Students had no prior biotechnology training and the intervention lasted four weeks. It comprised problem identification and solving, solution development, as well as a culmination competition. In the assessment, significant changes with respect to motivation (mean 2.7 to 4.1, d 0.54) and comprehension (mean 8.7 to 18 out of 20, d 0.92) were noted in pretest-posttest analysis. In the observation, interview and document analysis, participants noted improvement with respect to good communication, articulation of complex ideas, increased self-confidence, and effective use of visual aids. The major premise of the BioVate model, the ability to tackle real problems (for example, the use of CRISPR technology for developing pest-resistant crops), was reported to have fostered intrinsic motivation and closed the theoretical-practical gap. These findings also support constructivist learning theory and self-determination theory by highlighting the impact of competition and collaboration on engagement. This new approach contributes to increasing comprehensive conceptual understanding in biotechnology and builds skills in future educators and science communicators to address societal issues with an interdisciplinary approach.

Keywords*: Biotechnology, BioVate competition, conceptual understanding, science communications, science education.*

INTRODUCTIONS

From healthcare and agriculture to environmentalism, biotechnology has established itself as a pillar of modern science. In a world moving forward with unprecedented scientific and technological development, biotechnology is essential in trying to solve the pressing issues of climate change, food deficits, and public health emergencies (Bentahar et al., 2023). The influence of biotechnology, however, is not limited to laboratories and industries; it has the ability to connect the wider society with the scientific world (Dida, 2024). In order for this connection to be fruitful, scientists need to share their insights with the public. Bench scientists are known to produce extremely innovative products, however, with the lack of effective communication, the advancements will remain hidden to the wider world. This is where educators provide immense advantages, they can break down complex science messaged to children who are the future citizens of the world who would be living in a technology dominant world (Ferreira et al., 2018).

The communication of science is not just about converting complex words into simpler ones. It is, to a certain degree, achieving common understanding and appreciation between the scientist, the teacher, and society as a whole (Davies, 2021). Future educators of science need to be able to appreciate the theoretical aspects of biotechnology, as well as its practice, so that they can articulate it to many different audiences (Spektor-Levy et al., 2009). This, however, seems to be a common problem that has gap between the theoretical knowledge as taught in classrooms and the actual know how in the practical world. This puts a lot of undergraduate students in science education departments into tedious apathy. Most have little motivation towards biotechnology on which, unfortunately, rests much of their role as teachers Biotechnology is so complex that it utterly overwhelms and disengages students. Additionally, absence of systems that would cultivate strong assertive communication skills makes them poor communicators of the scientific ideas and concepts. In sum, all these do not only complicate their educational endeavors but also their capacity to serve as teachers of a responsible and well-educated future generation.

Our preliminary work addressing science education students in Banten shows that less than half of the number of students is keen on biotechnology issues. Such lack of interest is rooted in the understanding that biotechnology is remote and not relevant to their locality even when in fact, most of the biotech products are already consumed in their daily lives, often without adequate understanding of the scientific processes involved. This gap engenders negative attitudes towards teaching and learning biotechnology in the future. One of the major problems that these students face is the jargon associated with biotechnology literature, which for the most part, does not resonate with their everyday speech. To help address this gap, students require a framework that will help them become motivated to source, read and engage critically with scientific literature. Interestingly, our surveys indicate that healthy competition may foster the needed motivation to drill deeper and explore more.

To bridge these gaps, novel pedagogical strategies are necessary. The integration of competition is a possible solution using learning models, such as the BioVate model, which focuses on project-based learning while incorporating competition elements. In this model, students form a small-teams to tackle real-world problems by proposing and presenting biotechnological solutions to a panel of judges. This model promotes hands-on motivation for students by providing them with a goal while also aiding in the merging of practical application and theoretical learning. Moreover, students learn how to express their ideas actively and convincingly as they talk about their projects, which helps develop their communication skills and prepares them for a future career in teaching. By making this subject ever engaging and relevant through the incorporation of core subjects into biotechnology like agriculture, medicine, and environmental science, interdisciplinary connections are put into focus. Further, students learn to trust each other, exchange ideas, and help one another, ensuring that they will be able to engage their own students confidently and effectively.

This study seeks to evaluate the BioVate model as a solution to the challenges in biotechnology education. Here, we want to investigate how this teaching model increases students' motivation, comprehension, and communication skills while pursuing the objectives of a productivity-oriented project. This research will benefit from the case study of the experiences and results of the third-year science education students at Universitas Sultan Ageng Tirtayasa to understand how effective competition-based learning is when incorporated in biotechnology curricula. The goal is that, in the end, science educators will be more empowered to close the gap between the scientific world and society, and to engage K-12 students in real life science in order to foster scientifically literate citizens.

RESEARCH METHODS

1. Research Methodology

This research was used quasi-experiment with one group pretest-posttest (Creswell & Guetterman, 2015). The goals were to examines the implementation and impact of the BioVate model, a competition-based learning intervention, on third-year science education students at Universitas Sultan Ageng Tirtayasa, Serang City, Banten. The study focused on 67 undergraduate students with no prior formal exposure to biotechnology, who participated in a four-week intervention started at September 20 to October 23, 2024. The study was designed to allow flexibility to investigate how the BioVate model influences motivation, comprehension of biotechnological concepts, and communication skills in an educational setting. Participants were selected based on their enrollment in a biotechnology course, ensuring homogeneity in their background and limited prior knowledge of the subject.

Data were collected through a mixed-methods approach to capture both quantitative and qualitative insights, utilizing a variety of tools tailored to specific purposes. Pretest and posttest surveys were administered to measure changes in students' motivation and conceptual understanding of biotechnology, providing numerical data for quantitative analysis. Classroom observations were conducted to assess the development of communication skills by documenting students' interactions, group dynamics, and presentation abilities during competition activities. Document analysis, including evaluation of project proposals and presentation materials, further supported the assessment of communication skills by examining the clarity, creativity, and scientific accuracy of students' outputs. Finally, interviews were conducted to gain deeper qualitative insights into students' motivations, perceptions, and overall experiences with the competition, summarized in table 1.

Table 1. Design of BioVate competition

Time	Stages	Data Collection Tools
Week 1	Problem Identification and Research Students identified a biotechnology-related challenge and conducted literature research to understand its scientific and societal implications	Pretest score, interviews, observations
Week 2	Solution Development Groups designed a solution using biotechnological tools such as gene editing, enzyme technology, or bioinformatics. They were encouraged to incorporate modern techniques like CRISPR-Cas9 or molecular detection	Observations
Week 3	Project Preparation and Practice Students prepared their presentations, focusing on clarity, creativity, and scientific accuracy. They practiced communicating their ideas effectively to ensure their proposals were accessible to a non-expert audience	Observations, document analysis
Week 4	Final Competition and Evaluation Each group presented their project to a panel of judges comprises of lecturers and biotechnologist.	Posttest score, interviews, observations, document analysis

2. Data analysis

Quantitative data (pretest/posttest scores) were analyzed using descriptive statistics and paired t-tests to identify significant changes in motivation and comprehension. Qualitative data (observations, interviews, documents) were analyzed thematically using open and axial coding. Triangulation was employed to cross-validate findings. For example, comparing interview responses about improved confidence with observational notes on presentation quality. This mixed-methods approach ensures a holistic understanding of the BioVate model’s feasibility and impact, aligning with the exploratory goal of generating insights for future iterations of the intervention.

RESULTS AND DISCUSSION

1. Impact on student motivation and comprehensive conceptual understanding.

The impact of the competitions on incerasing science education student motivation and comprehensive conceptual understanding are explored in the pretest and postest. Means, standard deviations and sample size for the student motivation are assesed by 5 scale Likert scale with 1-5 scores and student comprehensions assessed by 10 test items maximum 20 score, reported in table 2.

Table 2. Pretest and posttest score

	Pretest		**Posttest**		**Significance**	**Effect Size**
	Mean	SD	Mean	SD		
Student Motivations	2.7	0.5	4.1	0.3	*	0.54
Comprehension understanding	8,7	4	18	2	*	0.92

The combination of project-based learning and competition improved students' motivation and understanding in biotechnology education. As indicated by the quantitative data from pretest and posttest assessments, both metrics exhibited improvement: student motivation increased from a mean of 2.7 (SD = 0.5) to 4.1 (SD = 0.3), which is a medium effect size (d = 0.54), and comprehension scores improved from 8.7 (SD = 4) out of 20 to 18 (SD = 2) out of 20, which is a large effect size (d = 0.92). It is correct that competition placed within a project-designed competition framework enhances engagement and retention of information. In particular, the competitive component of the intervention probably increased students' intrinsic motivation due to the relevancy it created. Being able to present solutions for real-world problems (such as local farming problems in Banten) motivated students to obtain and use biotechnological knowledge, changing learning from a passive to goal-oriented activity. This is further substantiated by the posttest motivation scores which show reduced standard deviation, indicating that the test motivation scores among the participants improved in a more uniform manner.

The project-based framework assisted with comprehension in another way. Students were required to identify issues, as well as formulate and justify their solutions, which fostered the application of theory in practice. The large gains in comprehension scores suggest that the application of problem-solving skills to real-life situations advanced understanding of the more challenging concepts of genetic engineering and bioinformatics. The decreased variability in posttest comprehension (SD = 2) further illustrates the success of the intervention in achieving specific learning goals through competitive collaborative engagement because structured learning environments produced less variability in performance. In this regard, the combination of competition with project work resulted in a self-reinforcing system: learners were motivated to learn more because deeper engagement with the material drove understanding, and understanding increased their self-efficacy in articulating solutions. This approach not only seeks to fill educational voids but also equips future teachers to render scientific knowledge relevant and usable to multiple audiences.

2. Development of communication skills .

The effects of the competition on the improvement of science communication skills were analyzed using three sources of data: observations, interviews, and document analysis (Figure 1), with a particular focus on judgment scores. The data were examined through thematic coding to identify recurring ideas, as detailed in Table 3. Triangulation of these data sources was conducted to draw robust conclusions regarding the enhancement of science communication skills.

Table 3. Data resource and key findings

Data Resource	**Key Findings**
Observations	**Week 1.** Student seems hesitant to express their ideas during FGD. Limited interactions. Each member of the team do information retrieval and do scientific reading
	Week 2. Increased collaboration was observed, with students actively debating

	biotechnological solutions and rehearsing presentations with peer feedback. Information representation during FGD was observed.
	Week 3. The discussion flow improved as students developed better skills in communicating their ideas, supported by a scientific background. Their ability to present knowledge also increased
	Week 4. Final presentations showed marked improvement in clarity, creativity, and persuasiveness. Judges noted that students communicated complex concepts effectively, using visual aids and storytelling techniques.
Interviews	**Culture of seeking Information** Some student has aware to find the scientific 'back-up' to explain the phenomenon and finding solution. One of the participants said "Previously, I seek the information through google and social media without any filter, but now I am aware to find the credible resouce and the science behind."
	Increased Confidence Students reported feeling more confident in explaining biotechnological concepts after participating in the intervention. For instance, one student stated, "I used to feel nervous about speaking in front of others, but now I can explain my ideas clearly."
	Improved Clarity Several students mentioned that preparing for presentations helped them organize their thoughts better. Another student commented, "Breaking down complex ideas into simple terms made it easier for me to understand and teach them."
Document analysis	**Project Proposals and Presentation Materials** Documents revealed improvements in structuring arguments, integrating evidence, and addressing potential counterarguments. For instance, one group's proposal included a step-by-step explanation of CRISPR technology to help the farmer in Banten to help local varieties of Talas Beneng (*Xanthosoma undipes*) having resistance toward its pest Ulat Grayak (*Spodoptera litura*) targeted to the non-technical audience.
	Judges' Evaluation Scores Communication scores averaged 3,9 out of 5 for 17 groups, reflecting high-quality presentations characterized by logical flow, appropriate use of visuals, and clear explanations. However, their verbal communications and gestures still needed to improve.

The integration of competition-based frameworks and project-based learning (PjBL) into biotechnology education demonstrates significant potential to address longstanding challenges in higher education. Traditional lecture-based approaches often prioritize content delivery over skill development, leaving students passive and disconnected from real-world applications. In contrast, in the bioVate model, we combining structured problem-solving with competitive elements, aligned with broader educational trends emphasizing active learning, critical thinking, and student-centered pedagogies. The result shows that BioVate competititon enhances communication skills by embedding structured practice, collaboration, real-world relevance, and competition into biotechnology education. The statistically significant improvements in motivation (mean increase from 2.7 to 4.1) and comprehension (mean increase from 8.7 to 18 out of 20) reflect the transformative power of such strategies, mirroring findings from studies on applications of PjBL in preservice teacher (Dziob et al., 2022; Hujjatusnaini et al., 2022). These results suggest that integrating competition into project-based learning can create a dynamic environment where students are motivated to engage deeply with complex concepts while developing practical skills.

Figure 1. Sample of presentation work we used on document analysis

The observed outcomes resonate with prior research on Pand gamification in education. For instance, the large effect size for comprehension (d = 0.92) parallels to Jia et al. (2023) literature reviews, which found PjBL enhances knowledge retention and problem-solving abilities. Similarly, the medium effect size for motivation (d = 0.54) aligns with studies showing that competition fosters engagement by creating a sense

of purpose and urgency (Kalogiannakis et al., 2021). However, the BioVate model diverges from traditional PjBL by explicitly incorporating competition as a motivation, which may explain the heightened motivation compared to non-competitive PjBL implementations. The improvement in communication skills, evidenced by judges' evaluations and student reflections, also supports claims that collaborative, real-world tasks enhance learners' ability to articulate scientific ideas—a gap often unaddressed in lecture- based settings (Entradas et al., 2024).

The success of the BioVate competitions aligns with constructivist learning theory, which posits that knowledge is built through active engagement and social interaction (Diana et al., 2021; Maspul, 2024). By requiring students to solve problems such as designing CRISPR-based solutions for pest-resistant crops, the intervention encouraged learners to synthesize theoretical knowledge with practical applications, reinforcing their understanding and communication skills. The competitive element introduced an additional layer of self-determination theory, where autonomy (choosing problems), competence (mastering concepts), and relatedness (collaborating with peers) drove intrinsic motivation. Observations of increased collaboration and iterative feedback cycles further validate this theoretical framework, as students transitioned from isolated information retrieval to collective problem-solving—a shift that fosters deeper cognitive processing.

Despite being encouraging, the results come with limitations. Because the sample size was small and the time frame was short (four weeks), it may be difficult to generalise the findings, especially in regard to how well skills are retained over time. Furthermore, the judges' assessment of the participants' communication skills showed a discrepancy between their speech and their non-verbal gestures, indicating that there is a need for more comprehensive public speaking training.

CONCLUSIONS

The BioVate competition combines competitive teaching with project-based learning. It enhances students' motivation while improving their interpersonal skills and fosters a biotechnological understanding. The merging of these approaches has made biotechnology education significantly different. The implementation of these approaches has led to remarkable self-reported changes in problem-solving skills, motivation, and even scientific communication comprehension. Further studies are necessary concerning the impact of innovative teaching adoption within various educational contexts on educational practices over time.

REFERENCE

Bentahar, S., Abada, R., Ykhlef, N., Soumia, B., Rofia, A., & Ykhlef, N. (2023). Biotechnology: Definitions, Types and Main Applications. *YAMER Digital*, *22*(1), 563–575. https://doi.org/10.37896/YMER22.04/49

Creswell, J. W., & Guetterman, T. C. (2015). *Educational Research, 6th Edition*.

Davies, S. R. (2021). An Empirical and Conceptual Note on Science Communication's Role in Society. *Science Communication*, *43*(1), 116–133. https://doi.org/10.1177/1075547020971642

Diana, N., Yohannes, & Sukma, Y. (2021). The effectiveness of implementing project-based learning (PjBL) model in STEM education: A literature review. *Journal of Physics: Conference Series*, *1882*(1). https://doi.org/10.1088/1742-6596/1882/1/012146

Dida, G. (2024). Biotechnology towards energy crops. *CABI Agriculture and Bioscience*, *5*(1), 1–15. https://doi.org/10.1186/s43170-024-00245-y

Dziob, D., Górska, U., Kołodziej, T., & Čepič, M. (2022). Physics competition to inspire learning and improve soft skills: a case of the Chain Experiment. In *International Journal of Technology and Design Education* (Vol. 32, Issue 1). Springer Netherlands. https://doi.org/10.1007/s10798-020-09620-y

Entradas, M., Bauer, M. W., Marcinkowski, F., & Pellegrini, G. (2024). The Communication Function of Universities: Is There a Place for Science Communication? *Minerva*, *62*(1), 25–47. https://doi.org/10.1007/s11024-023-09499-8

Ferreira, R., Alves, B. L., Paiva, S. R. De, Fluminense, U. F., Valonguinho, C., & Castro, H. C. (2018). *Teaching Biotechnology : A Demand Still to be Fully Attended*. *4*, 13–18.

Hujjatusnaini, N., Corebima, A. D., Prawiro, S. R., & Gofur, A. (2022). the Effect of Blended Project-Based Learning Integrated With 21St-Century Skills on Pre-Service Biology Teachers' Higher-Order Thinking Skills. *Jurnal Pendidikan IPA Indonesia*, *11*(1), 104–118. https://doi.org/10.15294/jpii.v11i1.27148

Jia, L., Jalaludin, N. A., & Rasul, M. S. (2023). Design Thinking and Project-Based Learning (DT-PBL): A Review of the Literature. *International Journal of Learning, Teaching and Educational Research*, *22*(8), 376–390. https://doi.org/10.26803/ijlter.22.8.20

Kalogiannakis, M., Papadakis, S., & Zourmpakis, A. I. (2021). Gamification in science education. A systematic review of the literature. *Education Sciences*, *11*(1), 1–36. https://doi.org/10.3390/educsci11010022

Maspul, K. A. (2024). Enhancing Project-Based Learning in STEM Education with Integrated Technology and Coding. *Journal of Intelligent Systems and Information Technology*, *1*(1), 16–24. https://doi.org/10.61971/jisit.v1i1.20

Spektor-Levy, O., Eylon, B. S., & Scherz, Z. (2009). Teaching scientific communication skills in science studies: Does it make a difference? *International Journal of Science and Mathematics Education*, *7*(5), 875–903. https://doi.org/10.1007/s10763-009-9150-6