

The project-based learning model and its contribution to life skills in biology learning: A systematic literature network analysis

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Abstract: This review examines the potential of Project-Based Learning (PjBL) to enhance students' life skills in the field of biology, and analyzes the challenges that may hinder its implementation. Using a Systematic Literature Network Analysis (SLNA), which combines Bibliometrics Analysis (BA) and Systematic Literature Review (SLR), this study analyzed articles from SCOPUS that met specific criteria. The findings reveal that PjBL is associated with e-learning and blended learning, and that the majority of articles on PjBL were published in 2020, particularly in the Journal of Microbiology & Biology Education. Additionally, this SLNA highlights the contributions of these articles to the developing of various life skills in biology learning. By identifying key trends and insights from existing literature, this study sheds light on the potential of PjBL to enhance students' biology education and their ability to apply it in their daily lives.

Keywords: biology learning; COVID-19; project-based learning; systematic literature network analysis

Introduction

Biology learning is nature-based learning that can be sourced from anywhere, including the surrounding environment (Alimah, 2019). The expected learning outcomes are not only limited to students' understanding of biology as students must be able to implement biology in everyday life, as well as to participate and contribute to society (Anazifa & Hadi, 2016). Learning biology is closely related to practical activities. During the COVID-19 pandemic, many schools implemented an online system and some were implemented offline with several accompanying policies. The impact of the COVID-19 pandemic has brought several changes in the learning system, including flexible learning by using devices without being hindered by time and space (Dhawan, 2020; Sugiarto, 2020). Biology practicals usually conducted in schools are often performed independently by students at home. Thus it is more appropriate for teachers to apply project-based learning.

Project-based learning (PjBL) is a learning model that can produce creative, communicative, and collaborative students who can engage in critical thinking, skills necessary for the 21st century (Almulla, 2020; Winangun, 2021). Instead of motivating students to learn, project-based learning facilitates collaboration between teachers and parents, especially during a pandemic (Nuryati, 2020). The obstacles to implementing project-based learning during the pandemic were the readiness of teachers and parents to assist students and inadequate facilities (Utami, 2020).

Life skills are a person's ability to deal with problems that exist in everyday life and are required to prepare biology students to face the world outside of school or the world of work. These skills are obtained from students' habits in making works or solutions that occur in the surrounding environment, thus biology teachers should develop project-based learning that can improve students' life skills. Teachers and parents can accompany students in making biology projects both at school and at home using everyday problems. The roles of teachers, parents and the surrounding community play an important role in the success of PjBL learning (Prihatin, 2021). The basic problem that is difficult to solve is the teacher's lack of ability to develop syllabi and learning tools because they are less knowledgeable about today's technology, thus the information and resources used are still limited (Kurniati, *et al.*, 2021).

The development of the PjBL learning model is needed to find ways for biology students to develop their life skills. The implementation of PjBL before the pandemic was very effective in increasing student motivation and learning outcomes but when after the pandemic occurred, several obstacles arose including the facilities and human resources of educators and students who were less proficient in technology. Consequently, it is necessary to have learning assistance for students and students must further improve their literacy skills. In PjBL, students are required to design a project to solve an existing problem and the solutions are influenced by the students' mindset, thus there is diversity in solving existing solutions. This is influenced by self-efficacy as an affective aspect that influences how students think, motivate themselves, and build self-confidence in the learning process (Morin & Herman, 2022).

Previous research on life skills in biology students by Jaharudin (2018) reported that applying life skills can increase students' learning motivation in studying biology, however, they did not explain how or what learning model they used. Nazmi *et al.* (2019) showed that students' ability to develop life skills is influenced by self-regulation and PjBL can improve life skills. The PjBL evaluation needs to be conducted to evaluate the appropriate implementation; this can be achieved by Systematic Literature Network Analysis (SLNA). SLNA research was conducted by Colicchia *et al.* (2019) with the title information sharing in supply chains: a review of risks and opportunities using the SLNA besides that there is also a systematic literature review research on Science Process Skills which shows that these skills can be honed with Discovery Learning (Idris *et al.*, 2022). However, SLNA research has not been performed in the field of biology learning. Therefore, this review analysed the implementation of the PjBL model and its contribution to aspects of students' life skills in biology learning. This article contributes to efforts to develop students' life skills in the 21st century, which can be encouraged by implementing a consistent and appropriate PjBL model.

Method

This study implemented a qualitative approach using the SLNA method. SLNA is a combination of internet/network analysis using the Bibliometric Analysis method and article or literature analysis techniques using the Systematic Literature Review method. In the first stage, a Systematic Literature Review (SLR) was conducted consisting of three stages, namely: (1). Scope of the analysis. In this phase, the topics are selected according to the research questions and this is achieved to obtain specifications in discussing the articles obtained. (2). Locating studies. Researchers formulate keywords to identify relevant articles to address the research questions. In this stage, the researcher also determines the timespan, type of document, and the language used as material for identifying relevant articles. (3). Study selection and evaluation. The research results are used to discuss the interrelationships and the output of these three stages provides an overview of the potential for further research development.

The second stage of the SLNA methodology is the NA, a citation network analysis that relies on reference lists of articles or journal publications by showing previous contributions that have influenced the development of their research (Martinez-Perez *et al.*, 2020). Even though there are various subjective reasons for someone to choose an article to be used as a reference, it is considered a measure of the influence that the article has; the more citations, the greater the influence of the article (Falagas *et al.*, 2013; Paiva *et al.*, 2012; Wang *et al.*, 2019). Therefore, this stage analyses and visualises articles based on keywords, relevant authors, journals and the relationship between these elements. Trends in the development of international publications in the field of PjBL were analysed using Vos-viewers software and the data were obtained from the SCOPUS database. In total, 111 relevant articles were identified and 20 articles were selected for analysis based on the criteria in Table

in using biology tools and databases so that students can appreciate and take advantage of the great potential of biology in life (Achappa *et al.*, 2020).

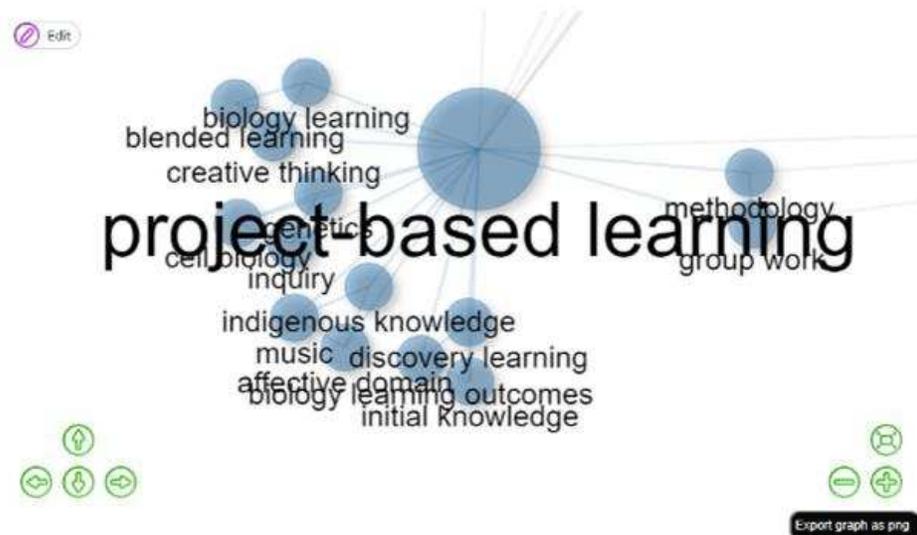


Figure 2. Display of the theme network in the bibliometrics application

Learning by participating in everyday environments is a great way to learn to apply biology concepts (Hamidah *et al.*, 2014). Learning processes that are not demanding can increase student motivation and help students naturally learn by themselves. Game-based learning can also be applied in the PjBL learning process and can maintain a fun learning atmosphere to train memory of the material that has been obtained by racing the pre-prepared questions so that to start a project students can be more materially and mentally prepared (Prochazkova *et al.*, 2019). Game-based learning can also be carried out at home online or offline (Heim & Holt, 2021) so that students' social skills will develop and learning becomes more interesting.

Year

During the last five years (2018-2022), most articles about PjBL in 2020 ranged from late 2019 to early 2020 (Figure 3), indicating that the emergence of the COVID-19 pandemic pushed education to adapt, thus PjBL became the choice of many educators.

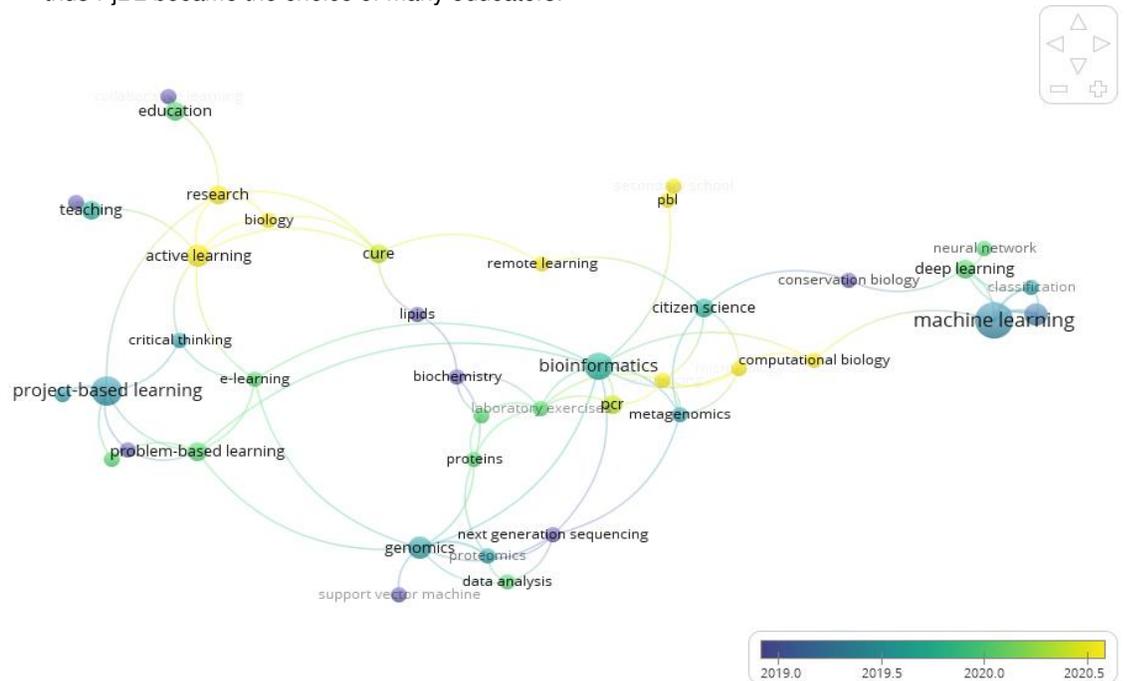


Figure 3. The publication year of articles in the Vosviewer application

The COVID-19 pandemic occurred at the end of 2019 and continues to increase in 2020 (Cucinotta & Vanelli, 2020; Roziqin *et al.*, 2021). Furthermore, it has gradually changed the educational paradigm and many changes have occurred since it emerged in 2020. The world of education must be responsive to transform from face-to-face (synchronous) teaching to asynchronous. It was during this period that all elements adapted to find effective solutions to ensure that learning was effective and remained meaningful for students. With the shift to online learning during the COVID-19 pandemic, various learning possibilities have emerged, in particular, PjBL (Randazzo *et al.*, 2021). PjBL is considered the most adaptive and best when combined with e-learning or blended, thus is widely used (Almulla, 2020).

Most relevant source

The most relevant source was the Journal of Microbiology and Biology Education (Figure 4), which was used as a source of reference and additional views for biology teachers to find the appropriate application of the PjBL model to improve students' life skills.

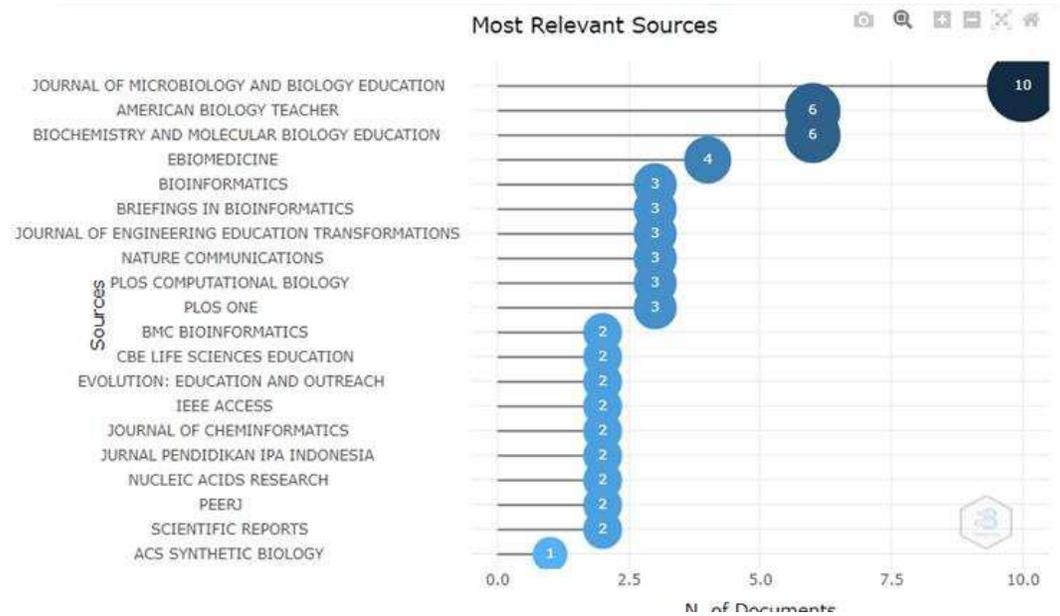


Figure 4. Most relevant sources in the bibliometrics application

The Journal of Microbiology & Biology Education (JMBE) offers original, previously unpublished, peer-reviewed articles that foster scholarly teaching, and provide readily adoptable resources in biology education at the undergraduate, graduate, professional (e.g., medical school), K-12 outreach, and informal education level. JMBE is edited by informed science educators who are active in the pursuit of scholarly teaching and biology education reform. It operates under a continuous publication model whereby manuscripts are made available online as soon as they become ready. The scope of this journal is rooted in biological sciences and related disciplines and it publishes articles addressing such topics as good pedagogy and design, student interest and motivation, recruitment and retention, citizen science, and institutional transformation. JMBE may also choose to accept manuscripts for publication in special-themed issues, which intersect with several scientific disciplines, for example, ethics in science, scientific citizenship, and science communication (American Society for Microbiology, 2023). During the COVID-19 pandemic, there were several published articles related to PjBL that could be used as references, including those related to the project-based learning approach to genomics (Pérez-Losada *et al.*, 2020), remote online project (Adil *et al.*, 2021), and improving student attitudes and academic performance (Burks, 2022).

Contribution and linkage to life skills

It is known that PjBL is learning that begins with stimulus questions that guide students in carrying out projects and this learning prioritises the process of reconstruction and application of theory into reality (Anggraini & Wulandari, 2021; Eliza *et al.*, 2019). The PjBL model tends to provide results in the form of increased thinking power and reinforcement of biology concepts for students and increases the creative thinking skills of teachers (Rodríguez-Martín *et al.*, 2020). It has been proven that the PjBL

model is effective in improving the communication skills and work management of student groups (Elsamanoudy *et al.*, 2021) and can increase student learning motivation, develop student skills and train students to solve problems (Sakilah *et al.*, 2020). This model allows students to discover new concepts from learning (David, 2018) and produces Soft Skill abilities (Cartono *et al.*, 2018) which are useful for supporting the hard skills and abilities of students in a social environment.

However, the benefits of implementing PjBL did not always produce good results due to the accompanying constraints. Obstacles in implementing the PjBL model so far have been related to several aspects of teachers, students, the environment, and learning media. The teacher's lack of ability to prepare learning elements that are appropriate to biology material affects students' understanding. Fewer spatial abilities will make learning difficult but if the learning environment is positive, this will help the learning process to develop students' spatial abilities and achieve good learning outcomes, and vice versa. If the aspects of educators, students, and the environment have succeeded in achieving positive outcomes but are not supported by adequate learning facilities, the student learning process will be hampered. In addition, limited time in working on projects and students who are less responsible and focused are the biggest obstacles (Sakilah *et al.*, 2020). Existing constraints must be reduced to maximise the potential results and teachers can be creative by combining several learning models and methods to reduce constraints and achieve the desired learning goals.

PjBL learning begins with problem mapping by students in their environment based on the stimulus of questions given by the teacher so that student inspiration increases (Snell-Rood *et al.*, 2021). Visualisation of study material is good for stimulating students' biology material concepts so that they will find it easier to find solutions to the problems (Fried *et al.*, 2020). Integration of several learning methods into the PjBL model plays a role in reducing the obstacles that arise so that e-learning blended learning which emphasises hands-on practice and balances reinforcement of biology material concepts is good for developing students' life skills (Yustina *et al.*, 2020).

Learning that involves teamwork and hands-on practice can further improve students' mastery of biology concepts (Carrasco *et al.*, 2019). By understanding biology concepts, students will find it easier to solve related problems, that is, acquire problem-solving skills. Direct practical learning in everyday life allows students to compare and integrate theoretical concepts into reality. In addition, students' social skills towards conceptual understanding or application of concepts emerge so as well as being able to apply concepts according to material into everyday life, they can also find theories that are in accordance with reality (Sukmawati *et al.*, 2019). Students can apply their scientific fields and adjust their learning by integrating several learning methods into the PjBL model (Urlica *et al.*, 2019). In addition, it is important to prepare cooperative educators and learning companions for students because their behaviour and patterns of education shape the learning character and character of students so that they will carry over to applications in society (Waddell *et al.*, 2021). Furthermore, respect and appreciation will be greater if learning based on direct practice in the field takes place with the right assistance (Pavlova *et al.*, 2021) so that students' life skills will develop according to the norms of society without the misuse of their biological knowledge.

Biology students' life skills will develop during the learning process using the PjBL learning model. Project-based learning requires students to go directly into the environment, make direct observations with research, and understand and reason more deeply about the surrounding environment. Students also develop good hard and soft skills because apart from understanding deeper concepts, students learn to use study aids, can discuss with friends and teachers, are used to paying attention to their surroundings, have a greater sense of responsibility and discipline, and are more confident to communicate other people's ideas and opinions and implement their learning outcomes in the surrounding environment. Therefore, to produce biology graduates who can carry out a social cognitive perspective and can build constructive abilities and self-evaluate their learning outcomes (Bravo *et al.*, 2018), think critically about problems and create solutions that exist in the surrounding environment (Mutakinati *et al.*, 2018), the implementation of the PjBL learning model must be in collaboration with the application of several learning methods and models adapted to biology material that maximise learning outcomes and reduce existing learning constraints. Thus automatically, if PjBL is applied in everyday life, the life skills of biology students will develop, provided that they are accompanied by the appropriate methods, models and materials.

The purpose of implementing projects in biology learning is to improve students' life skills (Jaharudin, 2018) and this can be achieved by using the Project Budbrust learning method which is a direct research project activity performed carried out at home in addition to increasing students' research abilities and understanding of biological concepts. This can also bring students closer to their parents and the community in their environment (Lichti *et al.*, 2021). Direct research using simple tools and materials at home can be applied to several biology materials to become a solution to the problems that exist during the implementation of PjBL during the pandemic. Providing problem-based learning methods that exist in the students' environment can help them to be directly involved in the environment (Colorado *et al.*, 2021).

Conclusion

Based on the analysis conducted, this study suggests that Project-Based Learning (PjBL) is associated with e-learning and blended learning, and its implementation can improve biology students' life skills through project activities based on daily life. However, the COVID-19 pandemic has posed obstacles to learning biology with PjBL, including a lack of understanding of concepts and difficulty finding necessary materials. To overcome these challenges, information and communication technology can be utilized, and the practical application of concepts in real-life scenarios can be emphasized. Additionally, e-learning and blended learning can directly facilitate PjBL and promote creativity and collaboration among students, ultimately leading to more active learners.

It should be noted that this study has certain limitations, such as the narrow focus on specific keywords and themes, limited publication years, and a lack of analysis of research methods, author demographics, and funding sources due to time constraints. Therefore, further research is needed to provide a more comprehensive and in-depth analysis of PjBL and its implications for biology education.

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Conflicts of Interest

The authors declare that there is no conflict of interest regarding of this paper.

Author Contributions

I. Y. N. Hizqiyah: Writing — original draft; Writing — review and editing. **F. V. Akuma:** Writing — review and editing; Formal analysis. **C. Cartono:** Writing — review and editing. **Y. Ibrahim:** Writing — review and editing. **I. Nurlaela:** Writing — review and editing. **M. Yanti:** Writing — review and editing. **S. Nuraeni:** Writing — original draft; Data Analysis; Writing — review and editing.

References

- Achappa, S., Patil, L. R., Hombalimath, V. S., & Shet, A. R. (2020). Implementation of project-based-learning (Pbl) approach for bioinformatics laboratory course. *Journal of Engineering Education Transformations*, 33(Special Issue), 247–252. <https://doi.org/10.16920/jeet/2020/v33i0/150154>
- Adil, A., Sami, S., & Morales, T. P. (2021). Remote online project: Traveling in a virtual world, researching microbes. *Journal of Microbiology & Biology Education*, 22(1), 10–12. <https://doi.org/10.1128/jmbe.v22i1.2367>
- Alimah, S. (2019). Kearifan lokal dalam inovasi pembelajaran biologi: Strategi membangun anak indonesia yang literate dan berkarakter untuk konservasi alam. *Jurnal Pendidikan Hayati*, 5(1), 1–9. <https://doi.org/10.33654/jph.v5i1.574>
- Almulla, M. A. (2020). The effectiveness of the project-based learning (PBL) approach as a way to engage students in learning. *SAGE Open*, 10(3), 1–15. <https://doi.org/10.1177/2158244020938702>
- American Society for Microbiology. (2023). *About JMBE*. American Society for Microbiology (ASM). <https://journals.asm.org/journal/jmbe/about>
- Anazifa, R. D., & Hadi, R. F. (2016). Pendidikan lingkungan hidup melalui pembelajaran berbasis proyek (project- based learning) dalam pembelajaran biologi. *Prosiding Symbion (Symposium on Biology Education)*, 453–462. [http://symbion.pbio.uad.ac.id/prosiding/prosiding/ID_333_Rizqa Devi_Revisi_Hal 453-462.pdf](http://symbion.pbio.uad.ac.id/prosiding/prosiding/ID_333_Rizqa%20Devi_Revisi_Hal_453-462.pdf)
- Anggraini, P. D., & Wulandari, S. S. (2021). Analisis penggunaan model pembelajaran project based learning dalam peningkatan keaktifan siswa. *Jurnal Pendidikan Administrasi Perkantoran*, 9(2), 292–299. <https://doi.org/10.26740/jpap.v9n2.p292-299>
- Bravo, R., Ugartemendia, L., Cubero, J., Uguz, C., & Rodríguez, A. B. (2018). Collaborative active learning: Bioimpedance and anthropometry in higher education. *Advances in Physiology Education*, 42(4), 605–609. <https://doi.org/10.1152/advan.00106.2017>
- Burks, T. N. (2022). Improving student attitudes and academic performance in introductory biology

- using a project-based learning community. *Journal of Microbiology & Biology Education*, 23(1), 1–9. <https://doi.org/10.1128/jmbe.00216-21>
- Carrasco, G. A., Behling, K. C., & Lopez, O. J. (2019). A novel grading strategy for team-based learning exercises in a hands-on course in molecular biology for senior undergraduate underrepresented students in medicine resulted in stronger student performance. *Biochemistry and Molecular Biology Education*, 47(2), 115–123. <https://doi.org/10.1002/bmb.21200>
- Cartono, c., Hizqiyah, I. Y. N., & Aryanti, F. (2018). Pengembangan softskill mahasiswa calon guru melalui pemberdayaan unit kegiatan mahasiswa di Universitas Pasundan. *Jurnal Komunikasi Pendidikan*, 2(1), 69–76. <https://doi.org/10.32585/jkp.v2i1.66>
- Colicchia, C., Creazza, A., Noè, C., & Strozzi, F. (2019). Information sharing in supply chains: A review of risks and opportunities using the systematic literature network analysis (SLNA). *Supply Chain Management*, 24(1), 5–21. <https://doi.org/10.1108/SCM-01-2018-0003>
- Colorado, H. A., Mendoza, D. E., & Valencia, F. L. (2021). A combined strategy of additive manufacturing to support multidisciplinary education in arts, biology, and engineering. *Journal of Science Education and Technology*, 30(1), 58–73. <https://doi.org/10.1007/s10956-020-09873-1>
- Cucinotta, D., & Vanelli, M. (2020). WHO declares COVID-19 a pandemic. *Acta Bio-Medica : Atenei Parmensis*, 91(1), 157–160. <https://doi.org/10.23750/abm.v91i1.9397>
- David, A. A. (2018). Using project-based learning to teach phylogenetic reconstruction for advanced undergraduate biology students: Molluscan evolution as a case study. *American Biology Teacher*, 80(4), 278–284. <https://doi.org/10.1525/abt.2018.80.4.278>
- Dhawan, S. (2020). Online learning: A panacea in the time of COVID-19 crisis. *Journal of Educational Technology Systems*, 49(1), 5–22. <https://doi.org/10.1177/0047239520934018>
- Eliza, F., Suriyadi, S., & Yanto, D. T. P. (2019). Peningkatan Kompetensi psikomotor siswa melalui model pembelajaran project based learning (PjBL) di SMKN 5 Padang. *INVOTEK: Jurnal Inovasi Vokasional Dan Teknologi*, 19(2), 57–66. <https://doi.org/10.24036/invotek.v19i2.427>
- Elsamanoudy, A. Z., Fayez, F. Al, Alamoudi, A., Awan, Z., Bima, A. I., Ghoneim, F. M., & Hassanien, M. (2021). Project-based learning strategy for teaching molecular biology: A study of students' perceptions. *Education in Medicine Journal*, 13(3), 43–53. <https://doi.org/10.21315/eimj2021.13.3.5>
- Falagas, M. E., Zarkali, A., Karageorgopoulos, D. E., Bardakas, V., & Mavros, M. N. (2013). The impact of article length on the number of future citations: A bibliometric analysis of general medicine journals. *PLoS ONE*, 8(2), 1–8. <https://doi.org/10.1371/journal.pone.0049476>
- Fried, E., Martin, A., Esler, A., Tran, A., & Corwin, L. (2020). Design-based learning for a sustainable future: student outcomes resulting from a biomimicry curriculum in an evolution course. *Evolution: Education and Outreach*, 13(1), 1–22. <https://doi.org/10.1186/s12052-020-00136-6>
- Hamidah, A., Sari, E. N., & Budianingsih, R. S. (2014). Persepsi siswa tentang kegiatan praktikum biologi di laboratorium SMA negeri se-Kota Jambi. *Jurnal Sainmatika*, 8(1), 49–59. <https://media.neliti.com/media/publications/221111-persepsi-siswa-tentang-kegiatan-praktiku.pdf>
- Heim, A. B., & Holt, E. A. (2021). From bored games to board games: student-driven game design in the virtual classroom. *Journal of Microbiology & Biology Education*, 22(1), 1–6. <https://doi.org/10.1128/jmbe.v22i1.2323>
- Hernawati, D., Amin, M., Irawati, M., Indriwati, S., & Aziz, M. (2018). Integration of project activity to enhance the scientific process skill and self-efficacy in Zoology of Vertebrate teaching and learning. *Eurasia Journal of Mathematics, Science and Technology Education*, 14(6), 2475–2485. <https://doi.org/10.29333/ejmste/89940>
- Husamah, H. (2015). Thinking skills for environmental sustainability perspective of new student of biology education department through blended project based learning model. *Jurnal Pendidikan IPA Indonesia*, 4(2), 110-119. <https://doi.org/10.15294/jpii.v4i2.3878>
- Husamah, H., Suwono, H., Nur, H., & Dharmawan, A. (2022a). Environmental education research in Indonesian Scopus indexed journal: A systematic literature review. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, 8(2), 105–120. <https://doi.org/10.22219/jpbi.v8i2.21041>
- Husamah, H., Suwono, H., Nur, H., & Dharmawan, A. (2022b). Sustainable development research in Eurasia Journal of Mathematics, Science and Technology Education: A systematic literature review. *Eurasia Journal of Mathematics, Science and Technology Education*, 18(5), em2103. <https://doi.org/10.29333/ejmste/11965>
- Idris, N., Talib, O. & Razali, F. (2022). strategies in mastering science process skills in science experiments: A systematic literature review. *Jurnal Pendidikan IPA Indonesia*, 11(1), 155-170. <https://doi.org/10.15294/jpii.v11i1.32969>
- Jaharudin, J. (2018). Aplikasi pendidikan kecakapan hidup (life skill) pada mata pelajaran biologi dalam meningkatkan hasil belajar biologi siswa kelas VIII MTsN Model Makassar. *Jurnal Pendidikan*, 6(2), 1–14. <https://doi.org/10.36232/pendidikan.v6i2.34>
- Khairani, E., Maksum, H., Rizal, F., & Adri, M. (2022). Efektivitas pengembangan modul pembelajaran berbasis project based learning selama pandemi pada matapelajaran TIK di sekolah menengah

- pertama negeri. *Scaffolding: Jurnal Pendidikan Islam Dan Multikulturalisme*, 4(1), 81–92. <https://ejournal.insuriponorogo.ac.id/index.php/scaffolding/article/view/1262/669>
- Kurniati, T., Yusup, R., Hermawati, A. S., Kusumawardani, D., Wijayanti, D., & Irhamudzikri, I. (2021). Respon guru terhadap kendala proses pembelajaran biologi di masa pandemi COVID-19. *Jurnal Educatio FKIP UNMA*, 7(1), 40–46. <https://doi.org/10.31949/educatio.v7i1.765>
- Lichti, D., Mosley, P., & Callis-Duehl, K. (2021). Learning from the trees: Using project budburst to enhance data literacy and scientific writing skills in an introductory biology laboratory during remote learning. *Citizen Science: Theory and Practice*, 6(1), 1–12. <https://doi.org/10.5334/CSTP.432>
- Martinez-Perez, C., Alvarez-Peregrina, C., Villa-Collar, C., & Sánchez-Tena, M. Á. (2020). Current state and future trends: A citation network analysis of the academic performance field. *International Journal of Environmental Research and Public Health*, 17(15), 1–24. <https://doi.org/10.3390/ijerph17155352>
- Morin, S., & Herman, T. (2022). Systematic literature review: Keberagaman cara berpikir siswa dalam pemecahan masalah. *Jurnal Pembelajaran Matematika Inovatif*, 5(1), 271–286. <https://doi.org/10.22460/jpmi.v5i1.271-286>
- Mutakinati, L., Anwari, I., & Yoshisuke, K. (2018). Analysis of students' critical thinking skill of middle school through stem education project-based learning. *Jurnal Pendidikan IPA Indonesia*, 7(1), 54–65. <https://doi.org/10.15294/jpii.v7i1.10495>
- Nazmi, Anggoro, B. S., & Haka, N. B. (2019). Pengaruh model pembelajaran life skill terhadap keterampilan generik biologi ditinjau dari self regulation. *Jurnal Bioterdidik*, 7(1), 72–85. <http://jurnal.fkip.unila.ac.id/index.php/JBT/article/view/17179/pdf>
- Nuryati, D. W., Masitoh, S., & Arianto, F. (2020). Pengaruh project based learning terhadap kreativitas peserta didik di masa pandemi. *Jurnal Teknologi Pendidikan*, 5(2), 98–106. <https://doi.org/10.32832/educate.v5i2.3375>
- Paiva, C. E., Lima, J. P. da S. N., & Paiva, B. S. R. (2012). Articles with short titles describing the results are cited more often. *Clinics*, 67(5), 509–513. [https://doi.org/10.6061/clinics/2012\(05\)17](https://doi.org/10.6061/clinics/2012(05)17)
- Pavlova, I. V., Remington, D. L., Horton, M., Tomlin, E., Hens, M. D., Chen, D., Willse, J., & Schug, M. D. (2021). An introductory biology research-rich laboratory course shows improvements in students' research skills, confidence, and attitudes. *PLoS ONE*, 16(12 December), 1–27. <https://doi.org/10.1371/journal.pone.0261278>
- Penn, M., & Mavuru, L. (2020). Assessing pre-service teachers' reception and attitudes towards virtual laboratory experiments in life sciences. *Journal of Baltic Science Education*, 19(6), 1092–1105. <https://doi.org/10.33225/JBSE/20.19.1092>
- Permana, F. H., Chamisijatin, L., & Zaenab, S. (2021). Blended learning berbasis project-based learning untuk meningkatkan kemampuan berpikir kritis. *JINoP (Jurnal Inovasi Pembelajaran)*, 7(2), 209–216. <https://doi.org/10.22219/jinop.v7i2.10353>
- Pérez-Losada, M., Crandall, K. M., & Crandall, K. A. (2020). Testing the “Grandma Hypothesis”: characterizing skin microbiome diversity as a project-based learning approach to genomics. *Journal of Microbiology & Biology Education*, 21(1), 1–8. <https://doi.org/10.1128/jmbe.v21i1.2019>
- Prihatin, P. (2021). Peran orang tua dan kendala yang dihadapi dalam pembelajaran di rumah (daring) saat pandemi COVID-19. *Mahaguru: Jurnal Pendidikan Guru Sekolah Dasar*, 2(1), 146–154. <https://ummaspul.e-journal.id/MGR/article/view/1882>
- Prochazkova, K., Novotny, P., Hancarova, M., Prchalova, D., & Sedlacek, Z. (2019). Teaching a difficult topic using a problem-based concept resembling a computer game: Development and evaluation of an e-learning application for medical molecular genetics. *BMC Medical Education*, 19(1), 1–8. <https://doi.org/10.1186/s12909-019-1817-2>
- Radivojević, T., Costello, Z., Workman, K., & Garcia Martin, H. (2020). A machine learning Automated Recommendation Tool for synthetic biology. *Nature Communications*, 11(1), 1–14. <https://doi.org/10.1038/s41467-020-18008-4>
- Randazzo, M., Priefer, R., & Khamis-Dakwar, R. (2021). Project-based learning and traditional online teaching of research methods during COVID-19: An investigation of research self-efficacy and student satisfaction. *Frontiers in Education*, 6(May), 1–16. <https://doi.org/10.3389/educ.2021.662850>
- Riza, M., Kartono, K., & Susilaningsih, E. (2020). Kajian project based learning (PjBL) pada kondisi sebelum dan pada saat pandemi COVID-19 berlangsung. *Seminar Nasional Pascasarjana UNNES*, 237–241. <https://proceeding.unnes.ac.id/index.php/snpsasca/article/download/617/536>
- Rodríguez-Martín, M., Vergara, D., & Rodríguez-González, P. (2020). Simulation of a real call for research projects as activity to acquire research skills: Perception analysis of teacher candidates. *Sustainability (Switzerland)*, 12(18), 1–17. <https://doi.org/10.3390/SU12187431>
- Roziqin, A., Mas'udi, S. Y. F., & Sihidi, I. T. (2021). An analysis of Indonesian government policies against COVID-19. *Public Administration and Policy*, 24(1), 92–107. <https://doi.org/10.1108/PAP-08-2020-0039>

- Sakilah, S., Yulis, A., Nursalim, N., Vebrianto, R., Anwar, A., Amir, Z., & Sari, I. K. (2020). Pengaruh project based learning terhadap motivasi belajar Sekolah Dasar Negeri 167 Pekanbaru. *JMIE (Journal of Madrasah Ibtidaiyah Education)*, 4(1), 127–142. <https://doi.org/10.32934/jmie.v4i1.175>
- Snell-Rood, E. C., Smirnoff, D., Cantrell, H., Chapman, K., Kirscht, E., & Stretch, E. (2021). Bioinspiration as a method of problem-based STEM education: A case study with a class structured around the COVID-19 crisis. *Ecology and Evolution*, 11(23), 16374–16386. <https://doi.org/10.1002/ece3.8044>
- Spence, P. L., Phillips, R. S., McAllister, A. R., White, S. L., & Hollowell, G. P. (2020). Student-scientist curriculum: integrating inquiry-based research experiences and professional development activities into an introductory biology laboratory course. *Journal of Microbiology & Biology Education*, 21(3), 1–12. <https://doi.org/10.1128/jmbe.v21i3.2225>
- Sugiarto, A. (2020). Dampak positif pembelajaran online dalam sistem pendidikan keperawatan pasca pandemi COVID-19. *Jurnal Perawat Indonesia*, 4(3), 432–436. <https://doi.org/10.32584/jpi.v4i3.555>
- Sukmawati, F., Setyosari, P., Sulton, & Purnomo. (2019). The effect of project-based collaborative learning and social skills on learning outcomes in biology learning. *Journal for the Education of Gifted Young Scientists*, 7(4), 1325–1344. <https://doi.org/10.17478/jegys.630693>
- Urlica, A. A. D., Coroama-Dorneanu, L. I., Kamberi, L., & Malenko, N. (2019). Sustainable learning and material development in ESP - English for the life sciences. *International Journal for Quality Research*, 13(3), 753–760. <https://doi.org/10.24874/IJQR13.03-16>
- Utami, E. (2020). Kendala dan peran orangtua dalam pembelajaran daring pada masa pandemi COVID-19. *Prosiding Seminar Nasional Pascasarjana UNNES*, 471–479. <https://proceeding.unnes.ac.id/index.php/snpasca/article/download/637/555>
- Waddell, E. A., Ruiz-Whalen, D., O'Reilly, A. M., & Fried, N. T. (2021). Flying in the face of adversity: A drosophila-based virtual CURE (Course-based undergraduate research experience) provides a semester-long authentic research opportunity to the flipped classroom. *Journal of Microbiology & Biology Education*, 22(3), 1–10. <https://doi.org/10.1128/jmbe.00173-21>
- Wang, M., Zhang, J., Jiao, S., & Zhang, T. (2019). Evaluating the impact of citations of articles based on knowledge flow patterns hidden in the citations. *PLoS ONE*, 14(11), 1–19. <https://doi.org/10.1371/journal.pone.0225276>
- Wardani, D. N., Toenlio, A. J., & Wedi, A. (2018). Daya tarik pembelajaran di era 21 dengan blended learning. *Jurnal Kajian Teknologi Pendidikan*, 1(1), 1–18. <http://journal2.um.ac.id/index.php/jktp/article/view/2852>
- Winangun, I. M. A. (2021). Project based learning: Strategi pelaksanaan praktikum IPA SD di masa pandemi COVID-19. *Edukasi: Jurnal Pendidikan Dasar*, 2(1), 11–20. <https://doi.org/10.55115/edukasi.v2i1.1388>
- Yustina, Y., Syafii, W., & Vebrianto, R. (2020). The effects of blended learning and project-based learning on pre-service biology teachers' creative thinking skills through online learning in the COVID-19 pandemic. *Jurnal Pendidikan IPA Indonesia*, 9(3), 408–420. <https://doi.org/10.15294/jpii.v9i3.24706>