Jurnal Pendidikan Sains Indonesia 11(2), p.345-359, (2023)
(Indonesian Journal of Science Education) e-ISSN: 2615-840X p-ISSN: 2338-4379
URL: http://jurnal.unsyiah.ac.id/JPSI/index DOI: doi.org/**10.24815/jpsi.v10i4.28541**

Application of Problem-Based Learning Model STEM-Based on Biology Lessons for High School Students Communication Skills

Gamar Shamdas*[1], Mursito Bialangi[1], Amalia Buntu[1], Ihwan[2]

[1]Program Studi Pendidikan Biologi Fakultas Keguruan dan Ilmu Pendidikan Universitas Tadulako, Palu, Indonesia.
[2]SMA Negeri Model Terpadu Madani, Palu, Indonesia.

*Email: gamar.shamdas@gmail.com

Article History:
Received date: October 15, 2023
Received in revised from: March 16, 2023
Accepted date: March 25, 2023
Available online: April 27, 2023

Citation:
Shamdas, G., Bialangi, M., Buntu, A., & Ihwan. 2023. application of problem-based learning model stem-based on biology lessons for high school students communication skills. *Jurnal Pendidikan Sains Indonesia (Indonesian Journal of Science Education)*, 11(2):345-359.

Abstract. Good quality communication skills are not evenly distributed among students in secondary schools. This quantitative study with a quasi-experimental method aims to describe high school students' communication skills through STEM-based PBL learning in Biology, describe high school students' oral and written communication skills through STEM-based PBL learning in Biology, and describe high school students' communication skills through PBL-based learning and STEM in Biology lessons by gender. The research design is a posttest only control design carried out on class XI students of SMAN Terpadu Madani Palu with a population of 7 classes totaling 220 students. The research sample used 2 classes totaling 64 students. Determination of the sample by purposive sampling considering the number of students and cognitive abilities of students in 2 classes are homogeneous. Data on written communication skills were obtained through tests using multiple-choice reasoned given during the post-test. Data on oral communication skills were obtained through observation of student activities during the learning process. The results showed that Biology learning by applying STEM-based PBL had a significant effect on the communication skills of high school students compared to direct STEM-based learning, written communication skills were better than oral communication skills and female students' communication skills were significantly better than male students.
Keywords: communication skills, written, oral

Introduction

Communication skills are indispensable in facing competition in various aspects of life in the 21st century because this ability is one of the four skills needed to build intellectual, emotional, spiritual, and transcendental intelligence (Yuniarti & State, 2016). Communication skills not only facilitate students in their education but prepare them for future careers (Riemer, 2007). Therefore, schools need to prepare their students with communication skills in all fields of study and at all levels of education continuously and sustainable (Fitriani & Ilyas, 2019) through effective training on how to understand, manage and create spoken and written words that can be used to communicate in a variety of forms and contexts (Hill, 2021; Sahin, 2009).

Good communication skills must be considered when training students, especially the quality of writing skills clearly and creatively as well as speaking well and effectively

(Ting et al., 2017). Students with good communication skills will demonstrate their ability to deliver presentations, express ideas, listen to, and provide good and appropriate feedback (Kamaruzaman et al., 2020). It will be clear when they express opinions and argue during discussions (Lubis et al., 2020). Communication skills with this quality can be used as direct experience as well as preparation for the social environment after school because good communication skills are needed for an effective work system with various teams in many fields of work and are used for collaboration in improving work skills and career advancement (Erdoğan, 2019).

Students with good communication skills are not evenly distributed in all schools in several countries, including Indonesia. Low communication skills, among others, are found in University of Education students, Winneba (Asemanyi, 2015), Biology class high school students in Madiun Regency (Sasmito et al., 2017), in learning mathematics for junior high school students in Bandung Regency (Mulqiyono et al., 2018), and in science learning in six districts in Lampung Province (Astuti et al., 2020). This situation is also found in high school students in Palu City, especially in learning biology.

The low communication skills still found in students at school reflect that teachers have not maximally implemented the learning process mandated in the 2013 curriculum. The 2013 curriculum emphasizes a student-centered scientific learning approach (Dikdas, 2019), and there have been many research results that report the effectiveness of the scientific approach in improving communication skills (Hast et al., 2019; Rizawati, 2022; Rizki & Sari, 2021; Yulia et al., 2018). However, there are many limiting factors related to efforts to improve good communication as some report that there are factors that affect communication skills, including the willingness of students to communicate (Rihardini et al., 2021), teacher-student relationship (Yunus et al., 2011), teacher communication style in teaching (Duta et al., 2015), learning approach used (Awang & Daud, 2015), and the knowledge and role of the teacher in designing learning (Bashir et al., 2016; Pedro et al., 2004). The skills, abilities and creativity of teachers are needed to design an interactive learning environment that can excite students to learn (Fındıkoğlu & İlhan, 2016; Yusof & Halim, 2014). So it has the potential to trigger students to generate ideas and train them to be skilled in oral and written communication (Wang, 2012).

Teachers can create interactive learning by applying innovative models, including problem-based learning (Astuti et al., 2017; Sekarwangi et al., 2021. The effectiveness of PBL in learning has been widely reported. Including helping students develop their insights (Gómez, 2016), improve learning achievement and problem-solving skills (Aslan, 2021; Lidyawati et al., 2017; Rezkillah & Haryanto, 2020), increase self-confidence (Mulyani et al., 2020), improve students' communication skills (Nurbaiti et al., 2016; Setyawan et al., 2021) good oral communication (Sedubun et al., 2019; Wati et al., 2019), reading skills (Seken & Artini, 2013) and writing skills (Durga & Rao, 2018). On the other hand, the presence of technology in learning today is unavoidable. It greatly affects the learning process because technology is not only a provider of unlimited access to knowledge but also a co-creator of information, mentors, and assessors. (Ferdousi & Bari, 2015; Haleem et al., 2022) useful for teaching and learning constructivism targeting effective solutions for pedagogical content and practice (Abdulrahaman et al., 2020; Greve & Tan, 2021). Therefore, it becomes necessary to integrate technology into the PBL learning model to create more meaningful learning.

Technology-based PBL research in STEM in improving communication skills has never been conducted on high school students in Palu City, especially in Biology learning. This kind of research is important because it can inform how to improve students' communication skills about real problems using technology and engineering in an integrated way in Biology learning. In addition, the findings obtained can be used as the basis for development research in Biology learning. Teachers can also use the results in designing lessons for other Biology materials. Therefore, the purpose of this study was to

describe the communication skills of high school students through STEM-based PBL learning in Biology subjects, describe the oral and written communication skills of high school students through STEM-based PBL learning in Biology subjects and describe high school students' communication skills through STEM-based PBL learning in Biology subjects by gender.

Methods

This study uses a quantitative approach with a quasi-experimental method. The research design is posttest only control design. This design tests behavior by changing one condition and observing its effect on other things (Arikunto, 2013).

The research was carried out at SMAN Terpadu Madani Palu in Class XI students. The population is all Class XI students, totaling 220 students enrolled in the 2021-2022 Academic Year and spread over seven classes. The sample used two classes, one experimental and one control class, with 64 students. The sample was determined by purposive sampling, considering that the number of samples in each class was the same, namely 32 students, and the cognitive abilities of students in both classes were relatively homogeneous. (data source: school). The experimental class applies the STEM-based PBL learning model, and the control class uses the STEM-based direct learning model.

Data on communication skills were obtained by distributing tests and making observations. Tests in the form of multiple choice reasoned to obtain data on written communication skills were given after learning was applied. Data on oral communication skills were obtained through observation of student activities during the learning process. Based on the data collection technique, the instrument used was a test for the variable written communication skills and an observation sheet for the variable verbal communication skills.

Five indicators of oral communication are modified from Chang et al., (2011), shown in Table 1. The six components of written communication assessment are modified from Mulia & Krisant (2014). Data on oral and written communication abilities in the experimental and control class were analyzed using an independent t-test because according to Sugiyono (2013) that an independent t-test was used to test samples with two treatments. However, it is determined beforehand that the data to be tested is normally distributed through the normality test and homogeneity of variance test for uniformity of data variance. Data analysis using SPPS version 25.0. In addition, the percentage of each indicator of written communication ability is calculated using the following formula.

$$\% \text{ of each indicator} = \frac{Total\ score}{Maximum\ scores}\ x\ 100\% \qquad (1)$$

Table 1. Verbal communication indicators

No.	Indicator Communication	Observed aspects
1	Expressing	Able to describe data through multiple representations: a. Can convert raw data into an easy-to-understand form and present it
		Able to explain the relationship between data: b. Can describe data relationships through graphs or signs
2	Evaluating	Able to understand the meaning of data presented by various Representations
		Able to view messages through various ways or aspects

		Able to justify the truth of data or arguments
		Able to distinguish fact and inference
3	Responding	Able to clarify ambiguous messages
		Able to confirm messages from peers (ask for an explanation of the message that is not clear)
		Able to respond to messages from peers
4	Negotiating	Be able to distinguish the difference between one's ideas and those of colleagues
		Able to revise own ideas according to peer opinion
		Able to reach mutual consensus through discussion with peers

Results and Discussion

The results and discussion of the application of the STEM-based PBL learning model are presented following the pattern of (a) a description of its effect on high school students' communication skills in Biology, (b) their effect on oral and written communication skills of high school students in Biology and (c) their effect on communication skills. High school students by gender. The STEM-based PBL learning model significantly affects the communication skills of high school students in Biology lessons. The results of the normality analysis of data are presented in Table 2, and the results of descriptive statistical analysis and the results of the t-test analysis are presented in Table 3.

Table 2. Data Normality Analysis Results

Class	Kolmogorov-Smirnov[b]		
	Statistic	df	Sig.
PBL + STEM	.126	31	.200*
Direct + STEM	.170	22	.097

The results of the Kolmogorov-Smirnov test inform that data on communication skills in classes that apply the learning model PBL + STEM [D (31) = 0.126, p = 0.200] as well as direct learning models + STEM [D (22) = 0.170, p = 0.097] normally distribued.

Table 3. Results of Descriptive Statistical Analysis and Results of t-Test

No.	Descriptive Measures and Results of t-Test Analysis		Score
		Mean	79.7
1	PBL + STEM	Std. Deviation	2.43
		Free degrees	31
		Mean	78.3
2	Direct + STEM	Std. Deviation	1.52
		Free degrees	22
3	t-*test*		2.32
4	Sig. (2-*tailed*)		0.02

The results of the analysis using unpaired t-test (Table 3) show that communication skills in classes that apply the direct learning model + STEM (M = 78.3, SD = 1,52) significantly lower than the class that applied the PBL learning model + STEM (M = 79.7, SD = 2,43), $t(51) = 2.32$, $p < 0.02$. The results are supported by the two classes' average written and oral communication skills, as shown in Figure 1.

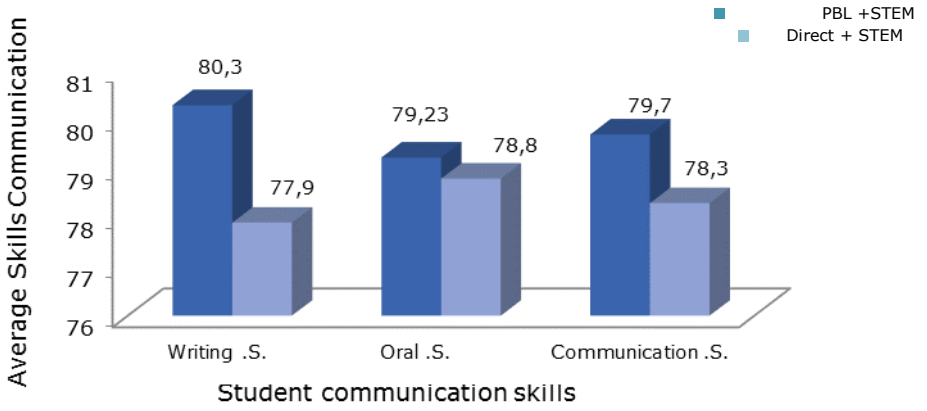

Figure 1. Average Value of Student Communication Skills

The results indicate that the communication skills of high school students in Biology subjects are significantly influenced by learning the STEM-based PBL model. In this learning, students are faced with a challenging situation to do many things in solving the problems identified in the PBL syntax, namely problem orientation. Authentic problems in everyday life, especially in the material on the structure and function of plant tissues, become interesting for students to solve with their group. This situation indirectly trains students to collaborate in verbal communication through discussions with their friends. Not only that, the teacher's guidance on investigation activities in the third PBL syntax seems clear that students are enthusiastic and very happy to carry out library searches to find many solutions to the problems discussed. The role of STEM in this section is also influential; namely, students are helped by their web-based technology facilities to explore as many sources as possible that provide information about the problem being studied. This finding is in line with the opinion of Bellanca & Stirling (2011) that to support learning and maximize the potential of communication skills, necessary to combine collaboration and technology because communication is naturally interwoven with collaboration. Several studies reported that the use of technology strongly supports student-centered learning because this media can facilitate and improve students' communication skills, interact interactively in learning and improve student learning achievements (Ammary, 2012; Bal & Bicen, 2017; Kivunja, 2014; Shieh, 2012). In addition, it is also informed that the STEM approach can develop many skills needed in the 21st century, including communication skills (Peters-burton & Stehle, 2019). The PBL learning model combined with the STEM approach significantly affects students' communication skills in science lessons (Kulsum et al., 2020).

The presence of STEM as a combination of science, technology, engineering, and mathematics integrated with PBL in Biology learning greatly influences students' communication skills in studying the structure and function of plant tissues. The benefits are felt when students are trained to build their experiences by assembling ideas through the knowledge they already know about this subject with new knowledge obtained from extensive searches of a number of information related to the solutions they want to find. It doesn't stop there, the ability of students to summarize a lot of data into a clear and concise short note and then express it in the form of exchanging information in small discussions is a surefire way to train students to use all their potential communication skills. This finding is supported by the opinion of Capraro et al. (2013) that STEM-based PBL learning naturally utilizes students' communication skills to share ideas and information effectively among group members. In addition, several research results inform that the STEM approach can improve communication skills from low to very high

categories (Widiastuti et al., 2022; Yulianti & Handayani, 2021), and PBL can improve communication skills (Batubara et al., 2022; Ernawati & Chotimah, 2022; Lufri et al., 2021). Combining PBL with STEM improves students' communication skills (Oktavia & Ridlo, 2020; Owens & Hite, 2020; Prabaningrum & Waluya, 2020; Suciari et al., 2021; Triana et al., 2020) because, in this learning, students more often participate in discussions. It is caused by the emergence of self-confidence, reduced anxiety, and higher self-efficacy when communicating with peers (Han et al., 2016).

The STEM-based PBL learning model significantly affects high school students' oral and written communication skills in biology subjects. The results of the normality analysis are presented in Table 4, and the descriptive statistical analysis and the t-test analysis results are presented in Table 5.

Table 4. Data Normality Analysis Results

Class	Kolmogorov-Smirnov[b]		
	Statistic	df	Sig.
Write Communication	.154	31	.060
Verbal communication	.137	31	.144

The results of the Kolmogorov-Smirnov test inform that the data on written communication skills [D (31) = 0.154, p = 0.060] and oral communication skills [D (31) = 0.137, p = 0.144] normally distributed.

Table 5. Results of Descriptive Statistical Analysis and Results of t-Test

	Descriptive Measures and Results of t-Test Analysis			Score
1	Write Communication		*Mean*	90.5
			Std. Deviation	2.80
		Free degrees		31
2	Verbal communication		*Mean*	79.5
			Std. Deviation	2.64
		Free degrees		31
3	t-*test*			15.8
4	Sig. (2-*tailed*)			0.001

The results of the analysis using unpaired t-test (Table 5) show that oral communication skills (M = 79.5, SD = 2,64) significantly lower than written communication (M = 90.5, SD = 2,80), t (60) = 15.8, p < 0.001, d = 1.78. The results indicate that students' written communication skills in Biology learning with STEM-based PBL is better than oral communication. Investigative activities in PBL while conducting integrated technology-assisted searches can help students to create and develop useful products in the form of new knowledge that can be used as alternative solutions to identified problems. Exploring many references that are related to the problem being studied helps students better understand the concept so that all the collected discourses, pictures, and various contextual conditions become a source of inspiration for students to write them down and make them as a result of work in solving the problems studied. This situation triggers students to write down their creative ideas using the right language based on the correct references, so that accurate and up-to-date information is produced related to the solution of the problem under study to be feasible to implement. Thus, all indicators of written communication related to the use of appropriate language, correct references, creative ideas, the feasibility of implementation, and accurate and up-to-date information are fulfilled, as shown in Figure 2. This finding is in line with other studies that reported that PBL successfully improved students' written communication rather than verbal communication (Maridi et al., 2019), especially mathematics writing

communication (Hafely et al., 2018; Madhavia et al., 2020; Nasution et al., 2021). In addition, the use of technology has a positive impact on students' writing quality (Patchan & Puranik, 2016; Wen & Walters, 2022), and STEM-based learning improves written communication in science lessons (Haryanti & Suwarma, 2018).

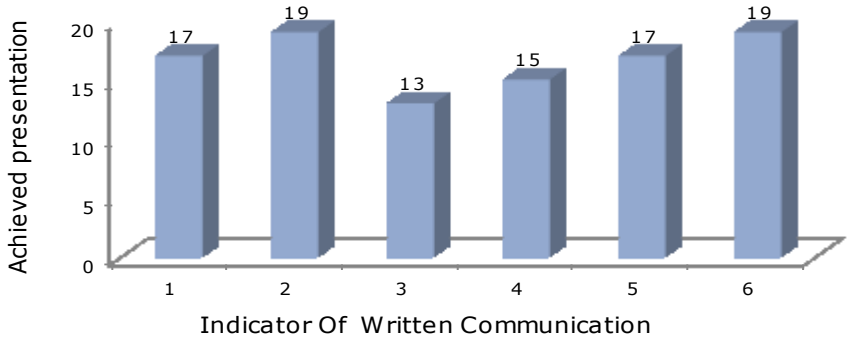

Figure 2. Percentage Achieved by Students on Each Written Communication Indicator
Note: 1= Correct use of language
2= Correct reference
3= Creative idea
4= Eligibility of implementation
5= Consistency between ideas and sources of information
6= Accurate and up-to-date information

The STEM-based PBL learning model significantly affects the communication skills of high school students based on gender. The results of the normality analysis are presented in Table 6, and the descriptive statistical analysis and the t-test analysis results are presented in Table 7.

Table 6. Data Normality Analysis Results

Gender	Kolmogorov-Smirnov[b]		
	Statistic	df	Sig.
Man	.161	12	.200*
Woman	.137	19	.200*

The results of the Kolmogorov-Smirnov test inform that the data on male communication skills [D (12) = 0.161, p = 0.200] as well as women [D (19) = 0.137, p = 0.200] normally distributed.

Table 7. Results of Descriptive Statistical Analysis and Results of t-Test

	Descriptive Measures and Results of t-Test Analysis		Score
1	Man	*Mean*	78.0
		Std. Deviation	2.41
		Free degrees	12
2	Woman	*Mean*	80.7
		Std. Deviation	1.79
		Free degrees	19
3	t-*test*		3.62
4	Sig. (2-*tailed*)		0.001

The results of the analysis using unpaired t-test (Table 7) shows that communication skills by gender are male (M = 78.0, SD = 2,41) significantly lower than female gender (M = 80.7, SD = 1,79), t (29) = 3,62, $p < 0.001$. The results indicate that the communication skills of female students taught by STEM-based PBL in Biology are better than that of male students. This learning succeeded in creating a pleasant learning atmosphere by involving students in several research activities and exploring the widest literature to find alternative solutions to the problem of plant tissue structure and function. This finding is in line with the results of research that informs that in STEM and PBL learning, female students have greater interest, can immediately respond to positive ideas, and like to work in groups because they believe it allows them to work with peers and improve their social skills (Younesa et al., 2020).

In the learning process that applies STEM-based PBL, the teacher indirectly trains students' creativity through learning while working and doing various engineering knowledge using the help of technology media. This learning situation spontaneously invites students to communicate verbally and in writing so that students become involved in meaningful learning, especially female students. This finding is supported by a study that reported that female students' communication skills were better than male students (Guezc et al., 2020) because females tend to be in meaningful learning while males are in rote learning. It is caused by differences in motivation, authority orientation, and responsibility (Jelas et al., 2005; Kılıç & Sağlam, 2010).

Conclusion

This study studied the communication skills of high school students through STEM-based PBL in Biology. The results showed that learning by applying STEM-based PBL had a significant effect on high school students' communication skills compared to direct STEM-based learning. Furthermore, the written communication skills were better than the oral communication skills of high school students in Biology. In addition, the communication skills of female students were significantly better than male students.

References

Abdulrahaman, M.D., Faruk, N., Oloyede, A.A., Surajudeen-Bakinde, N.T., Olawoyin, L. A., Mejabi, O.V., Imam-Fulani, Y.O., & Fahm, A.O. 2020. Multimedia tools in the teaching and learning processes: A systematic review. *Heliyon*, 6(11):2–14. https://doi.org/10.1016/j.heliyon.2020.e05312.

Ammary, J.A.l. 2012. Educational technology: a way to enhance student achievement at the University of Bahrain. In E. and T. The Association of science (ed.), *international conference on new horizons in education procedia - social and behavioral sciences,* p. 248–257. Elsevier Ltd. https://doi.org/10.1016/j.sbspro.2012.09.501.

Arikunto, S. 2013. *Prosedur penelitian suatu pendekatan praktik*. In Jakarta: Rineka Cipta (Ed. Rev. V), PT Rineka Cipta, Jakarta.

Asemanyi, A.A. 2015. An assessment of students ’ performance in communication skills a case study of the University of Education Winneba. *Journal of Education and Practice*, 6(35):1–7. https://files.eric.ed.gov.

Aslan, A. 2021. Problem-based learning in live online classes: Learning achievement, problem-solving skill, communication skill, and interaction. *Computers & Education*, 171:104237. https://doi.org/10.1016/j.compedu.2021.104237.

Astuti, R.D., Setyarini, M., & Jalmo, T. 2020. The importance of guided inquiry learning models to train communication skills. *IOSR Journal of Research & Method in Education (IOSR-JRME)*, 10(2):46–50. https://doi.org/10.9790/7388-1002034650.

Astuti, Siswandari, & Theo, D.S. 2017. E-Book for Problem based learning to improve learning outcome of the students. *Advances in social science, education and humanities research (ASSEHR)*, 158:220–227. https://www.atlantis-press.xn--com-ls0a.

Awang, H. & Daud, Z. 2015. Improving a communication skill through the learning approach towards the environment of engineering classroom. *Procedia - Social and Behavioral Sciences*, 195*:*480–486. https://doi.org/10.1016/j.sbspro.2015.06.241.

Bal, E. & Bicen, H. 2017. The Purpose of students' social media use and determining their perspectives on education. *Procedia Computer Science*, 120*:*177–181. https://doi.org/10.1016/j.procs.2017.11.226.

Bashir, M., Azeem, M., & Dogar, A.H. 2016. Factor effecting students' english speaking skills. *British Journal of Arts and Social Sciences*, 2(1):35–50. https://www.researchgate.net/351904246.

Batubara, I.H., Saragih, S., Simamora, E., Napitupulu, E.E., & Sari, I.P. 2022. Analysis of student's mathematical communication skills through problem based learning models assisted by augmented reality. *Budapest International Research and Critics in Linguistics and Education (BirLE) Journal*, 5(1):1024–1037. https://doi.org/10.33258/birci.v5i1.3704.

Bellanca, J.A. & Stirling, T. 2011. *Classrooms without borders: Using internet projects to teach communication and collaboration*. Teachers College Press, London.

Capraro, R.M., Capraro, M.M., & Morgan, J. 2013. *STEM project-based learning: An integrated science, technology, engineering, and mathematics (STEM) approach* (2nd ed.). Sense Publishers, Netherlands.

Chang, H.P., Chen, C.C., Guo, G.J., Cheng, Y.J., Lin, C.Y., & Jen, T.H. 2011. The Development of a competence scale for learning science: inquiry and communication. *International Journal of Science and Mathematics Education*, 9:1213–1233. https://www.researchgate.net/225647229.

Dikdas. 2019. *Amanat kurikulum 2013 melalui pendekatan saintifik*. Direktorat Guru Pendidikan Dasar, Jakarta.

Durga, M.V.S. & Rao, V.C.S. 2018. Developing students' writing skills in english-a process approach. *Journal for Research Schloars and Professionals of English Language Teaching*, 6(2):1–5. https://www.researchgate.net.

Duta, N., Panisoara, G., & Panisoara, I.O. 2015. The Effective communication in teaching. diagnostic study regarding the academic learning motivation to students. *Procedia - Social and Behavioral Sciences*, 186:1007–1012. https://doi.org/10.1016/j.sbspro.2015.04.064

Erdoğan, V. 2019. Integrating 4C skills of 21st century into 4 language skills in EFL classes. *International Journal of Education and Research*, 7(11):113–124. https://www.ijern.com.

Ernawati, T. & Chotimah, R.N. 2022. Problem-based learning as an effort to improve junior high school students' learning mastery and communication skills. *Wacana Akademika: Majalah Ilmiah Kependidikan*, 6(1):19–28. https://doi.org/10.47191/ijmra/v5-i3-17.

Ferdousi, B. & Bari, J. 2015. Infusing mobile technology into undergraduate courses for effective learning. *Procedia-Social and Behavioral Sciences*, 176*:*307–311. https://doi.org/10.1016/j.sbspro.2015.01.476.

Fitriani, S. & Ilyas, H.P. 2019. Communication skill : A challenge for vocational high school students in the 21 st century. *Jurnal Solma*, 8(1):150–158. https://doi.org/http://dx.doi.org/10.29405/solma.v8i1.3097.

Fındıkoğlu, F. & İlhan, D. 2016. Realization of a desired future: Innovation in education. *Universal Journal of Educational Research*, 4(11):2574–2580. https://doi.org/10.13189/ujer.2016.041110.

Gómez, L.A.B. 2016. *Problem-based learning: Enhancing oral communication in the EFL Classroom*. Universidad Externado de Colombia, Colombia.

Greve, K. & Tan, A. 2021. Reimagining the role of technology in higher education: the new normal and learners' likes. *Compass: Journal of Learning and Teaching*, 14(3):1–24. https://doi.org/10.21100/compass.v14i3.1231.

Guezc, A., Peyreabc, H., & Ramus, F. 2020. Sex differences in academic achievement are modulated by evaluation type. *Elsevier: Learning and Individual Difference*, 83:1-9. https://doi.org/10.1016/j.lindif.2020.101935.

Hafely, B.A., Jazuli2, L.O.A., & Sumarna, N. 2018. Pengaruh model pembelajaran problem based learning (PBL) terhadap kemampuan pemecahan masalah matematik siswa. *Jurnal Serunai Matematika*, 9(2):194–204. https://doi.org/10.37755/jsm.v12i2.309.

Haleem, A., Javaid, M., Qadri, M.A., & Suman, R. 2022. Understanding the role of digital technologies in education: A review. *Sustainable Operations and Computers*, 3:275–285. https://doi.org/10.1016/j.susoc.2022.05.004.

Han, S., M.Capraro, R., & M.Capraro, M. 2016. How science, technology, engineering, and mathematics project based learning affects high-need students in the U.S. *Learning and Individual Differences*, 51:157–166. https://doi.org/10.1016/j.lindif.2016.08.045.

Haryanti, A. & Suwarma, I.R. 2018. Profil keterampilan komunikasi siswa SMP dalam pembelajaran IPA berbasis STEM. *WaPFi (Wahana Pendidikan Fisika)*, 3(1):49-55. https://doi.org/10.17509/wapfi.v3i1.10940.

Hill, B. 2021. It's good to talk: Speaking up for oracy in the management classroom. *The International Journal of Management Education*, 19(2):79–89. https://doi.org/10.1016/j.ijme.2021.100462.

Hst, N.A., Syahputra, & Surya, E. 2019. Development of learning tools with a scientific approach to improve mathematical communication skills and student activities of SMK buana bahari medan. *Journal of Education and Practice*, 10(35):35–42. https://doi.org/10.7176/jep/10-35-05.

Jelas, Z.M., Rahman, S., Baki, R., & Ahmad, J. 2005. Prestasi Akademik Mengikut Gender. *Jurnal Pendidikan*, 30*:*93–111. https://www.researchgate.net/255643055.

Kamaruzaman, M., Hamid, R., Mutalib, A. ., & Rasul, M. . 2020. Communication skills attributes for IR 4.0 for engineering graduates. *European Journal of Molecular & Clinical Medicine*, 7(8):573–588. https://www.researchgate.net/346784107.

Kivunja, C. 2014. Do you want your students to be job-ready with 21st century skills? change pedagogies: A Pedagogical paradigm shift from vygotskyian social constructivism to critical thinking, problem solving and siemens' digital connectivism. *International Journal of Higher Education*, 3(3):81–91. https://doi.org/10.5430/ijhe.v3n3p81.

Kılıç, D. & Sağlam, N. 2010. Investigating the effects of gender and school type on students' learning orientations. *Procedia-Social and Behavioral Sciences*, 2(2):3378–3382. https://doi.org/10.1016/j.sbspro.2010.03.519.

Kulsum, U., Hariyadi, S., & Iqbal, M. 2020. The Effect of a stem approach with the problem based learning model on communicative skills and student learning outcomes. *ScienceEdu: Jurnal Pendidikan IPA*, 3(2):58–70. https://jurnal.unej.ac.id.

Kusmiarti, R., Yuniati, I., & Noermanzah. 2020. Improving student communication skills in learning indonesian language through collaborative learning. *International Journal of Scientific and Technology Research*, 9(1):207–211. https://www.researchgate.net/340980799.

Lidyawati, Gani, A., & Khaldun, I. 2017. Penerapan model problem based learning untuk meningkatkan hasil belajar dan keterampilan berpikir kritis peserta didik pada materi larutan penyangga. *Jurnal Pendidikan Sains Indonesia (Indonesian Journal of Science Education)*, 5(1):140–146. http://jurnal.unsyiah.ac.id/jpsi.

Lubis, N., Asnawi, & Pinem, N.J. 2020. Analyzing Indonesian EFL students' communication skill in debate classroom. *Journal of Linguistics, English Teaching and Education*, 1(1):15–19. https://ejurnal.seminar-id.com/index.php/jlee/79.

Lufri, Elmanazifa, S., & Anhar, A. 2021. The Effect of Problem-based learning model in information technology intervention on communication skills. *Jurnal Ta'dib*, 24(1):46–52. https://ojs.iainbatusangkar.ac.xn--id-i5t.

Madhavia, P., Murni, A., & Saragih, S. 2020. Pengaruh model problem based learning terhadap kemampuan komunikasi matematis siswa kelas VII SMP kabupaten kuantan singingi. *Jurnal Cendekia; Jurnal Pendidikan Matematika*, 4(2):1239–1245. https://doi.org/10.31004/cendekia.v4i2.357.

Maridi, M., Suciati, S., & Permata, B.M. 2019. Peningkatan keterampilan komunikasi lisan dan tulisan melalui model pembelajaran problem based learning pada siswa kelas X SMA improvement of oral and written communication skills through problem based learning model for high school students. *Jurnal Pendidikan Biologi*, 12(2):182–187. https://doi.org/10.20961/bioedukasi-uns.v.

Mulia, K. & Krisant, E. 2014. Communication skills course: Enhancing presentation and proposal-writing skills of chemical engineering students. *Communication_ Skills_Course_Enhancing_Presentation*, p.1–12. https://doi.org/ 10.18260/1-2—20182.

Mulqiyono, S., Yuniar, D., & Anita, I.W. 2018. Analisis kemampuan komunikasi matematik siswa kelas VIII pada materi bangun datar segitiga dan segi empat. *Jurnal Pembelajaran Matematika Inovatif*, 1(4):599–606. https://journal.ikip siliwangi.ac.id/index.php/jpmi/article/view/1015.

Mulyani, S., Gani, A., Syukri, M., Tarmizi, T., Elisa, E., Nurhasanah, N., & Fajriani, F. 2020. Penerapan model problem based learning pada materi alat-alat optik untuk meningkatkan kepercayaan diri dan kemampuan menyelesaikan masalah kontekstual. *Jurnal Pendidikan Sains Indonesia (Indonesian Journal of Science Education)*, 8(1):105–113. https://doi.org/10.24815/jpsi.v8i1.15666.

Nasution, H.A., Nurdalilah, & Wardani, H. 2021. Pembelajaran berbasis masalah untuk meningkatkan kemampuan komunikasi matematis siswa. *Jurnal MathEducation Nusantara*, 4(1):110–120. https://jurnal.pascaumnaw.ac.id/index.php/JMN/130.

Nurbaiti, S.I., Irawati, R., & Putri, R.L. 2016. Pengaruh pendekatan problem based learning terhadap kemampuan komunikasi matematis dan motivasi belajar siswa. *Jurnal Pena Ilmiah*, 1(1):1001–1010. https://ejournal.upi.edu/indexphp/pena ilmiah/3015.

Oktavia, Z. & Ridlo, S. 2020. Critical thinking skills reviewed from communication skills of the primary school students in STEM-based project-based learning model. *Journal of Primary Education*, 9(3):311–320. https://doi.org/10.15294/jpe.v9i3.27573.

Owens, A. & Hite, R. 2020. Enhancing student communication competencies in STEM using virtual global collaboration project based learning. *Research in Science and Technological Education*, 38(3):1–27. https://doi.org/10.1080/02635143.2020. 1778663.

Patchan, M.M. & Puranik, C.S. 2016. Using tablet computers to teach preschool children to write letters: Exploring the impact of extrinsic and intrinsic feedback. *Computers and Education*, 102*:*128–137. https://doi.org/10.1016/j.compedu.2016.07.007.

Pedro, F., Olivera, Susana, G., & Martínez. 2004. Empirical assessment of some learning factors affecting Spanish students of business English. *English for Specific Purposes*, 23(2):163–180. https://doi.org/org/10.1016/S0889-4906(02)00044-3.

Peters-burton, E.E. & Stehle, S.M. 2019. Developing student 21st century skills in selected exemplary inclusive STEM high schools. *International Journal of STEM Education*, 1:1–15. https://doi.org/10.1186/s40594-019-0192-1.

Prabaningrum, D. & Waluya, S.B. 2020. The Improvement of mathematical communication skill through project based learning with STEM strategy. *Proceedings of the International Conference on Science and Education and Technology*, p.646–651. https://doi.org/10.2991/assehr.k.200620.132.

Pratiwi, T.P., Munasir, M., & Suprapto, N. 2020. Enhancing students' science communication skills through more learning model. *JPPS (Jurnal Penelitian Pendidikan Sains)*, 10(1):12–24. https://doi.org/10.26740/jpps.v10n1.p1844-1856.

Rezkillah, I.I. & Haryanto, H. 2020. Pengaruh model pembelajaran problem based learning terintegrasi high order thinking skill terhadap kemampuan berpikir kritis dan sikap percaya diri. *Jurnal Pendidikan Sains Indonesia (Indonesian Journal of Science Education)*, 8(2):257–268. https://doi.org/10.24815/jpsi.v8i2.17322.

Riemer, M.J. 2007. Communication skills for the 21st century engineer. *Global Journal of Engineering Education,* 11(1):89–100. https://www.researchgate.net/299507876.

Rihardini, A.A., Yaniafari, R.P., & Mukminatien, N. 2021. Students willingness to communicate using english: a survey study. *Paramasastra*, 8(1):75–94. https://doi.org/10.26740/paramasastra.v8n1.p75-94.

Rizawatii, R. 2022. Meningkatkan kemampuan komunikasi (communication skill) dan hasil belajar siswa melalui pembelajaran saintifik dengan memanfaatkan media infografis. *Edutech : Jurnal Inovasi Pendidikan Berbantuan Teknologi*, 2(1):55–63. https://doi.org/10.51878/edutech.v2i1.976.

Rizki, N. & Sari, N. 2021. Meningkatkan keterampilan komunikasi siswa dengan menggunakan pendekatan saintifik pada mata pelajaran ilmu pengetahuan alam di SDN 035 Indrapuri 1A. *Jurnal Pendidikan Tambusai*, 5(1):1157–1165. https://jptam.org/index.php/jptam/article/view/1083.

Sahin, M.C. 2009. Instructional design principles for 21st century learning skills. *Procedia-Social and Behavioral Sciences*, 1(1):1464–1468. https://doi.org/10.1016/j.sbspro.2009.01.258.

.

Sasmito, A., Suciati, & Maridi. 2017. Profile of communication skills in biology for Xi grade students of "Y" senior high school in madiun regency. *Unnes Science Education Journal*, 6(2):1555–1561. https://journal.unnes.ac.id/sju/index.php/usej/15818.

Sedubun, N., Tulung, G.J., & Kalangi, L.M.V. 2019. Improving students' oral competency through communicative language teaching approach. *Kajian Linguistik*, 7(1):18–29. https://doi.org/10.35796/kaling.5.2.2017.24785.

Sekarwangi, T., Sartono, K.E., Mustadi, A., & Abdullah. 2021. The effectiveness of problem based learning-based interactive multimedia for elementary school students. *International Journal of Elementary Education*, 5(2):308–314. https://ejournal.undiksha.ac.id/index.php/IJEE/article/view/31603.

Seken, K. & Artini, L.P. 2013. A study on strategies for teaching speaking and reading comprehension skills. *E-Journal Program Pascasarjana Universitas Pendidikan Ganesha*, 1:1-9. https://ejournal-pasca.undiksha.ac.id.

Setiawan, I.N., Roostika, M., Utami, S., Julie, H., & Panuluh, A.H. 2019. *Improving the communication skills of grade vii students for animals classification and set by using STEM approach*. In Y.D. Kristanto, A.H. Panuluh, B. Utomo, & P. Angelina (Eds.), *Improving Professionalism and Reflective Thinking through Design Research* (pp. 98–104). Sanata Dharma University Press, Yogyakarta.

Setyawan, D., Shofiyah, A., Dimlantika, I., Sakti, Y., & Susilo, H. 2021. Implementation of problem-based learning model through lesson study on student communication skills. *AIP Conference Proceedings*, 2330(1):1–4. https://pubs.aip.org/aip/acp/article/2330/1/030012/839793.

Shieh, R. 2012. The impact of technology-enabled active learning (TEAL) implementation on student learning and teachers' teaching in a high school context. *Computers & Education*, 59(2):206–214. https://doi.org/10.1016/j.compedu.2012.01.016.

Suciari, N.K., Ibrohim, & Sowono, H. 2021. The Impact of PJBL intgereted STEAM on student's communication skill and concept mastery in high school biology learning. *AIP Conference Proceedings*, 2330(1):1–10. https://doi.org/10.1063/5.0043395.

Sugiyono. 2013. *Metode Penelitian pendidikan pendekatan kuantitatif, kualitatif dan R&D*. Alfabeta, Bandung.

Ting, S.H., Marzuki, E., Chuah, K.M., Misieng, J., & Jerome, C. 2017. Employers' views on the importance of english proficiency and communication skill for employability in Malaysia. *Indonesian Journal of Applied Linguistics*, 7(2):315–327. https://doi.org/dx.doi.org/10.17509/ijal.v7i2.8132.

Triana, D., Anggraito, Y.U., & Ridlo, S. 2020. Effectiveness environmental change learning tools based on STEM-PjBL towards students' collaboration and communications skills. *Journal of Innovative Science Education*, 9(3):244–249. https://journal.unnes.ac.id/sju/index.php/jise/article/view/34048.

Wang, A.Y. 2012. Exploring the relationship of creative thinking to reading and writing. *Thinking Skills and Creativity*, 7(1):38–47. https://doi.org/doi.org/10.1016/j.tsc.2011.09.001.

Wati, M.Y., Maulidia, I.A., Irnawati, & Supeno. 2019. Keterampilan komunikasi siswa Kelas VII SMPN 2 Jember dalam pembelajaran IPA dengan model problem based learning pada materi kalor dan perubahannya. *Jurnal Pembelajaran Fisika*, 8(4):275–280. https://jurnal.unej.ac.id/index.php/JPF/article/view/15237.

Wen, X. & Walters, S.M. 2022. The impact of technology on students' writing performances in elementary classrooms: A meta-analysis. *Computers and Education Open*, 3:100082. https://doi.org/10.1016/j.caeo.2022.100082,

Widiastuti, I., Oktavia, S., Lukad, V., & Sutrisno, P. 2022. Analysis of student communication skills in STEM learning using engineering design process. *Proceedings of the International Conference on Industrial Engineering and Operations Management Istanbul, Turkey*, *Oecd* 2012:5212–5219. https:// ieomsociety.org/proceedings/2022istanbul/1054.

Younesa, R.G., Caprarob, R.M., Caprarob, M.M., Roslic, R., Leed, Y., Velae, K., & Danielle B. 2020. Jack and jill went up the hill, but jill won both ways: The True story about differential academic achievement. *International Journal of Innovation in Science and Mathematics Education,* 28(4):44–57. https://doi.org/10.30722/ijisme.28. 04.004.

Yulia, L., Yarmi, G., Yatimah, D., & Syarif, S.M. 2018. Improved skill speaks with a scientific approach in students of class IV SDN Jakasampurna 1V Kota Bekasi. *International Journal of Advances in Scientific Research and Engineering*, 4(8):92–96. https://doi.org/10.31695/ijasre.2018.32824.

Yulianti, D. & Handayani, E. 2021. Enhancement of communication skills through physics learning with science, technology, engineering, and mathematics (STEM) approach. *Journal of Physics: Conference Series*, 5:1-9. https://doi.org/10.1088/1742-6596/ 1918/5/052083.

Yuniarti, N. & State, Y. 2016. Essential skills for vocational education in 21. *Proceedings* International Conference Revitalization Of Vocational Education Ln Free Trade Era (ICERVED), 219–222. http://staffnew.uny.ac.id.

Yunus, M., Osman, W.S.W., & Ishak, N.M. 2011. Teacher-student relationship factor affecting motivation and academic achievement in ESL classroom. *Procedia-Social and Behavioral Sciences*, 15:2637–2641. https://doi.org/10.1016/j.sbspro.2011. 04.161.

Yusof, F.M. & Halim, H. 2014. Understanding teacher communication skills. *Procedia-Social and Behavioral Sciences*, 155:471–476. https://doi.org/10.1016/ j.sbspro. 2014.10.324.