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Effective learning model bases problem based learning and digital mind maps to improve student's collaboration skills

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ABSTRACT

Student's collaboration skills are still low while this skill is important for students. The selection of an active learning model is an attempt to overcome this problem. This study aimed to investigate the effects of problem based learning (PBL) and integrated PBL digital mind maps (DMM) on university students' collaboration skills. This quasi-experimental study employed a pretest-posttest control group design. The participants consisted of 103 students majoring in biology education from Riau, Indonesia. Each of the classes was randomly picked to act as the PBL group, integrated PBL-DMM group, and traditional group. The students' collaboration skills were observed using an observation sheet which contained aspects of responsibility, respect, contribution, organize work and work as a whole team. The data obtained were analyzed using analysis of covariance (ANACOVA) and least significance different (LSD) test. The ANACOVA results demonstrated some significant changes in both comparison groups: PBL and integrated PBL-DMM. In other word, learning models had an effect on students' collaboration skills. However, the LSD test proved that both learning models were not significantly different in improving students' collaboration skills, despite the fact that the students in the integrated PBL-DMM model class could perform better than those of PBL. Therefore, educators may either use PBL or integrated PBL-DMM in the classroom.

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1. INTRODUCTION

Learning cannot be separated from diverse life situations that keep changing. Even, the 21st century learning is evolving into more complex problem-solving that requires particular abilities and skills [1]. Due to its rapid development, learning has become a definite challenge for educators. Education plays a significant role in helping learners face a variety of problems posed by the 21st century era. Therefore, education needs to provide learners with many opportunities to be competent in adapting to new environment. In other words, the success of learners may be determined by skills and knowledge that they are using to adjust to changes [2], [3]. To achieve their goals, learners need to master the 21st century skills [4], such as collaboration skills [5].

Collaboration skills include the ability to show respect for diverse teams and to train flexibility and willingness to make compromises [6]–[8]. Collaboration involves sharing the rules and participation of team members in their respective roles and finding shared benefits [9] by understanding their strengths and

weaknesses. Collaboration allows people to solve mutual problems and achieve common goals [10] through the construction, monitoring, and improvement of shared knowledge during interactions that occur when collaborating [9].

The important role of collaboration skills in education places it as one of the key skills in the 21st century [11], [12]. Research shows that people with good collaboration skills are able to achieve better [13], energize others to create a shared vision to solve problems [14] and facilitate the work of others as well as identify and utilize other team members' abilities. Another study found that training students in collaboration could improve learning effectiveness [15]. Collaboration skills are needed by students to promote social competences including conflict resolution skills and academic self-concept [16].

Collaboration skills, needless to say, are very important in the learning process. These skills can be integrated into learning at different levels of education and disciplines [7]. Some research findings suggest that the Indonesian university students' collaboration skills need an improvement [17]. Students' collaboration can be fostered and carried out in the context of physical, social and cultural environments and more importantly in the educational environment which provides comfort for students to collaborate and express their ideas. Learners' collaboration requires learners' full engagement in the discussions. Therefore, the role of teacher or instructor, in this case, is only to facilitate learning [18].

The important role of collaboration skills in education places it as one of the key skills of the 21st century [11], [12], [19]. Study results show that people with good collaboration skills achieve better performance [13], have the ability to mobilize and energize others to create a shared vision of problem solving [14], [20], facilitates the work of others and can identify and utilize the various abilities of team members. Another study found that training students in collaboration can increase learning effectiveness. In other words, having good collaboration skills gave better results. Collaboration skills are also able to improve students' social competence including conflict resolution skills and academic self-concept [16].

Collaboration skills are skills that are recognized as very important in the learning process. However, empirical facts in the field still show the low collaboration skills of students. For example, Rohman [21] research which seeks to increase student collaboration through the inter-teams game tournament. Other studies also show low student collaboration [17], [22]. Basically collaboration can be integrated into the learning process at various grade levels and disciplines [7], can be fostered and carried out in the context of the physical, social and cultural environment and more importantly the educational environment must be comfortable enough for students to collaborate and express their ideas [23].

Problem based learning (PBL) is a learning model that can be used as an instructional alternative to help cope with the weaknesses of the traditional approach [24] and can increase student independence if implemented through the Computer Assisted Learning (CAL) method [25] as well as increase mastery concept [26]. PBL has been proven effective to build bases for learners to enrich knowledge, develop independent, and collaborative learning skills. Interactions between students in the groups form a collaborative learning [27]. PBL also bears some weaknesses. PBL learners are required to connect their background knowledge with information that is going to be learned. However, the majority of learners hardly do a brainstorming by referring to some references to solve a problem, while in fact prior knowledge determines processes that learners have to go through in making a link between the old and new information [28]. To resolve this PBL issue, students can be provided with a mind-mapping assignment. Mind maps can be helpful for students to delineate their background knowledge [29].

The structures in mind maps are radially arranged so that concepts can be organized visually in branches and marked with colors [30]. Mind maps are organized hierarchically where the main concepts are placed in the main branches while the others are grouped in the next levels as the details [31]. Mind maps can be created using digital media [32], [33]. These mind maps are usually called digital mind maps (DMM). The use of technological information tool is very important in learning [34]. The making of DMM utilizes application that helps the creator to connect the concepts of information using a connecting line to visualize and classify ideas [32], [35]. Incorporating DMM into PBL is expected to be more effective in promoting students' active engagement and collaborative learning in the classroom [36] and creativity [37]. The study focused to examine the effects of PBL and integrated PBL-DMM on university students' collaboration skills.

2. RESEARCH METHOD

2.1. Research design

This study used the pretest-posttest control group experimental design. This study was conducted for one semester in Universitas Islam Riau, Indonesia. The research sample was determined based on the results of a test to measure the homogeneity of the participants' academic levels. The total of 103 students majoring in biology education aged between 19-21 years old. These students were classified into three classes: i) PBL class (37 students); ii) PBL-DMM class (35 students); and iii) Conventional class (31 students).

The learning process in the three classes takes place with a different syntax. In conventional classes, students carry out discussions and then the lecturer explains the learning material. The role of the lecturer is more dominant in this class because the lecturer delivers the material using the lecture method. The stages of learning in the PBL class were: i) Students obtain worksheets containing discourse on problems and the lecturer acts as a facilitator to introduce problems and direct students to formulate actual problems; ii) Students look for various references to support problem solving; iii) Each group begin to discuss and collaborate in finding solutions to these problems. During this process, the lecturer provides guidance and assistance to each group; iv) Students make reports based on the findings they have obtained and present them to other class members. Students can give each other opinions or input; and v) At the end of the learning session, the lecturer provides feedback and concludes the lesson together.

In the PBL integrated DMM class, the learning steps were: i) Before students are oriented to the problem, the students first make a digital mind map DMM to review prior knowledge and relate it to the concepts learned; ii) The next step is orienting students to actual problems; iii) Organizing students to solve problems; iv) During the process of finding solutions to problems, students can use the DMM or add details to the DMM if they find new things during the process of finding solutions; v) Students make reports and present the results or findings obtained; vi) The last step is analyze and evaluate the problem solving process that has been carried out.

2.2. Research instrument and procedure

Lecture units, semester lecture plans, student worksheets and observation sheets were used as the research instruments. Indicators of collaboration skills that were measured included responsibility, respect, contribution, work organization, and teamwork [7]. Prior to data collection, instruments had to undergo expert validation. The results showed high validity of the instruments that is 94.44. The assessment rubric for students' collaboration skills can be seen in Table 1.

During the data collection process, the three groups of students were enrolled in different stages of learning. The Integrated PBL-DMM class performed learning through students were asked to create DMM and teacher asked the students some questions to elicit their background knowledge. Unlike the PBL-DMM class, the PBL students did not utilize DMM in learning. The learning process were oriented to problems and the end of learning students were asked to do reflection or evaluation on the solution and conclude the lesson. In the conventional class, students were engaged in learning that contain of the delivery of learning objectives, lectures on the materials, and lesson wrap-up.

Table 1. Collaboration skill rubric

Indicator	Score			
	4	3	2	1
Responsibility	Have high responsibility to complete the assigned tasks; always submit them on time	Have medium responsibility to complete the assigned tasks; often submit them on time	Have low responsibility to complete the assigned tasks; rarely submit them on time	Do not have any responsibility to complete the assigned tasks
Respect	Always polite and kind to the teammates and other classmates; acknowledge and respect the perspective of others	Often polite and kind to the teammates and other classmates; acknowledge and respect the perspective of others	Sometimes polite and kind to the teammates and other classmates; sometimes disrespect the perspective of others	Impolite and unkind to the teammates and other classmates (e.g., interrupt, ignore ideas, hurt feelings); disrespect the perspective of others
Contribution	Consistently and actively contribute knowledge, opinions, and skills; provide constructive feedback in details	Contribute knowledge, opinions, and skills when asked; provide constructive feedback in details when necessary	Occasionally contribute to the group (only when asked); provide constructive feedback	Do not provide any contribution at all
Organize Work	Create a detailed list of tasks; set a schedule and track the progress of goals and deadlines; save materials, drafts, and notes in an organized way	Create a more general list of tasks; set a schedule to do the tasks but occasionally ignore it; save materials, drafts, and notes in a less organized way	Work on tasks without creating a list of tasks; track progress and deadlines when requested; save materials, in a less organized way	Work on tasks without creating a list of tasks; save materials, drafts, and notes in a non-organized way (may be misplaced or inaccessible)
Work as a whole team	Recognize the special talents of the team; Individual tasks which have been done separately are brought to the team for feedback and revision	Make several attempts to use the special talents of the team members; work on several tasks separately and put them together at the end	Make a little effort to use the special talents of the team members; do most of the tasks separately and put them together at the end	Do not recognize nor use the special talents of the team members; do all the tasks separately and submit them as a collection of individual work

2.3. Data analysis

The data obtained were analyzed using analysis of covariance (ANCOVA) at 5% significance level. If the results successfully demonstrated effects of learning models on students' collaboration skills, a least significance different (LSD) test could be conducted. Before performing the ANCOVA analysis, the data normality and homogeneity were examined using Kolmogorov-Smirnov test and Levene test, respectively. The Kolmogorov-Smirnov test showed a normal distribution of data with p-value of 0.200, while the Levene test indicated homogeneous data with p-value of 0.663 (p-value > α (α=0.05).

3. RESULTS AND DISCUSSION

The collaboration scores of the integrated PBL-DMM students are significantly higher than those of the PBL and traditional classes as shown in Figure 1. The figure shows that all treatment groups, in general, reported better performance at responsibility and respect others compared to other collaboration skills assessed in the rubric. The highest responsibility score was observed in the integrated PBL-DMM class (92.63), while the highest score on respect others was found in the PBL class (91.70) and followed by the traditional class (82.04). Compared to other indicators, work as a whole team showed the lowest scores of integrated PBL-DMM (68.92), PBL (69.43), and traditional class (59.19).

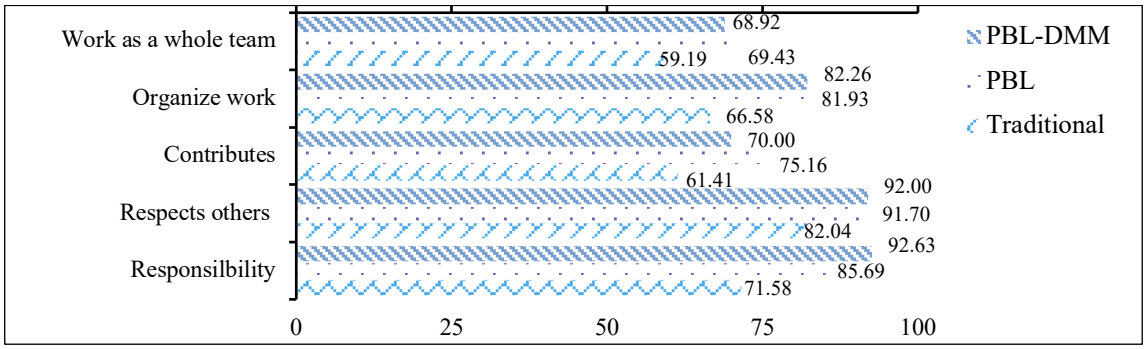

Figure 1. Students' collaboration scores

The collaboration indicator that has occupied the highest position in the integrated PBL-DMM class is responsibility. Regular DMM assignments may encourage students to become responsible for on-time task submission because in the DMM application there is also a time setting feature as presented in Figure 2. Responsibility is more than just helping one another because students must have worked collaboratively and be responsible for the results [38]. A responsible individual is emotionally bound to his goals. S/he will work hard to fulfill all responsibilities and has the urge to do the right things [8].

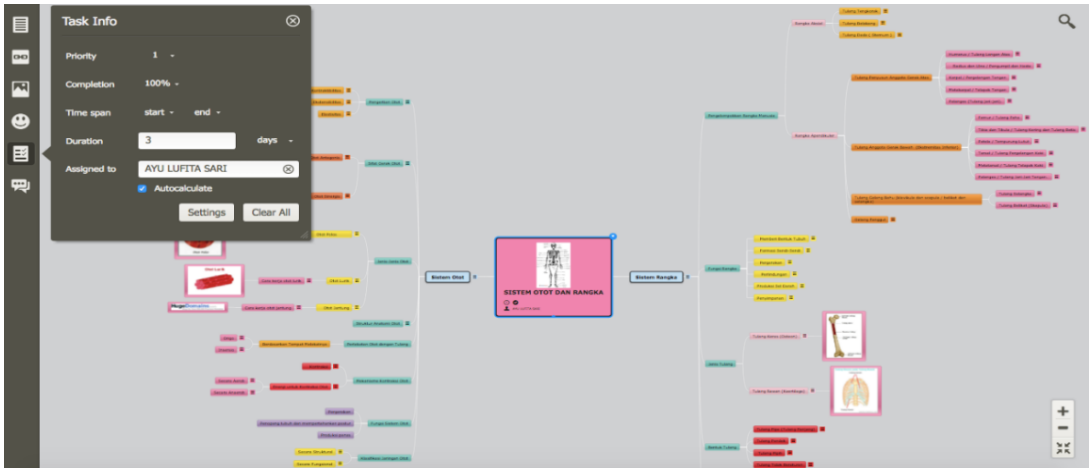

Figure 2. One of the setting time features of the DMM

Respect is one of the collaboration skills that achieved high scores in the PBL and traditional classes. The results of the observations indicate that students as a group member frequently show respect to other group members. An important component of collaboration is giving and receiving feedback. Peer feedback has many benefits in knowledge construction. It can function as a parameter to check the suitability of one's quality of work with the existing criteria [39]. Feedback can also provide opportunities for students to identify the strengths and weaknesses of their peers, suggest improvements to the work, and function as a self-assessment tool [39].

The lowest collaboration scores in the PBL and integrated PBL-DMM classes were observed in work as a whole team. Students cannot work together in a team because they are not accustomed to recognizing the distinctive abilities possessed by each of the group members. As a result, they cannot make use of the abilities and find it difficult to collaborate with others. Confirmed by findings of this research, teamwork requires the ability of each individual to work together to achieve common goals through sharing knowledge and skills. The literature consistently highlights the importance of "focus towards shared goals" as one of the important elements of a team [38]. Teamwork effectiveness is rooted in the knowledge possessed by each member of a group. An ANCOVA test was conducted based on the students' collaboration scores. The results of the test are presented in Table 2 and followed by the LSD statistics as summarized in Table 3.

Table 2 shows the difference in the results of the treatments with p-value=0.000 and F=78.474. Since p-value<α (α=0.05). The difference between PBL, integrated PBL-DMM and traditional learning in improving students' collaboration skills lies in the syntax. PBL and integrated PBL-DMM learning processes prioritize group work in problem solving. Therefore, each group member is given the opportunity to contribute to the problem-solving processes. Various activities that can take place in groups include identifying what needs to be learned from the problem, expressing opinions or ideas, listening to group explanations, dividing tasks so that they can be completed on time, and looking for references to solve problems [40], [41], emphasize that two of the three phases of PBL i.e. initial problem analysis and presentation of work results are very dependent on teamwork. The way students interact in groups has a positive effect on students' collaboration skills. These interactions usually occur in the process of formulating problems together, expressing ideas and assumptions that can clarify the facts introduced in the problem, helping group members, and providing explanations. In other words, a group is a complex social system that requires interactions between the members [27].

Table 2. ANCOVA analysis on students' collaboration skills

Source	Type III Sum of Squares	df	Mean square	F	Sig.
Model	8796.057[a]	3	2932.019	193.564	.000
Intercept	2676.047	1	2676.047	176.665	.000
Xcritical	6003.141	1	6003.141	396.311	.000
Classes	2377.378	2	1188.689	78.474	.000
Error	1090.624	72	15.148		
Total	478534.875	76			
Total average	9886.682	75			

a. R Squared=.890 (Adjusted R Squared=.885)

The findings of this study are corroborated with previous research findings that have already proven the positive effects of PBL on students' collaboration skills compared to traditional learning [42], [43]. The learning process carried out in a PBL classroom makes students more active, so they can develop various skills such as collaboration, problem formulation, information discovery, presentation, decision and conclusion making skills [28], [44]. PBL engages students in solving authentic problems, allowing them to design their own learning through the information search process. PBL also requires students to work collaboratively in solving problems [45]. Table 3 suggests that there was no significant difference between PBL and the integrated PBL-DMM in improving students' collaboration skills. Unlike the traditional class which was dominated by lecturing method, PBL and integrated PBL-DMM showed more significant effects on students' collaboration skills as seen in LSD notation in Table 3.

Table 3. The results of the LSD Test on students' collaboration skills

Class	Pretest	Post-test	Difference	Score increase	Average score	LSD notation
Traditional	64.886	69.043	4.157	6.41%	69.795	a
PBL	66.759	81.999	15.240	22.83%	81.432	b
PBL-DMM	66.019	82.782	16.763	25.39%	82.736	b

PBL and integrated PBL-DMM have similar effects on students' collaborative skills because both learning models emphasize the importance of group work in solving a problem. PBL and integrated PBL-DMM can encourage students to develop collaboration skills that include respect, contribution, work organization, teamwork, and responsibility. In a PBL classroom, the problem-solving process is carried out through team collaboration so that educators need to organize students and provide guidance along the way. The formation of teams or small groups is more efficient than individual learning in encouraging students to achieve learning goals [46].

Furthermore, PBL and integrated PBL-DMM also encourage students to work effectively in diverse teams to find solutions to problems and present them in a written form. Students must be able to make wise decisions when there is a difference of opinion. This process can lead to the improvement of the students' collaboration skills which is characterized by the ability to show respect for diverse teams, the willingness to make compromises needed to achieve common goals, and appreciate individual contributions to the team [6], [7].

Unlike PBL and integrated PBL-DMM, traditional learning apparently has a less significant effect on students' collaboration skills. Students in a traditional class usually experience learning through information transfer. This learning process does not allow students to contribute ideas or cooperate with their classmates. Learning shift from student-centered to peer tutoring. Students are used to individual tasks so that they cannot recognize or support each other. Group activities provide more opportunities for students to identify others' strengths and weaknesses and suggest improvements to their work [39]. Group activities also involve students in joint planning, monitoring, evaluation, and regulation of the social, cognitive, and behavioral aspects of their learning [47].

PBL and integrated PBL-DMM have been proven effective in improving university students' collaboration skills. Collaboration skills are important for university students to achieve their goals, especially in the 21st century era. The 21st century requires skillful individuals who are able to compete and quickly adapt to the new development. Besides collaboration skills, university students also need to acquire other skills, including communication skills [48], [49] and critical thinking skills [50], [51].

4. CONCLUSION

The effects of PBL and integrated PBL-DMM on students' collaboration skills are significant. However, the findings of this study suggest that PBL-DMM is more effective in promoting the skills. Therefore, it is highly recommended for teachers or lecturers to incorporate PBL or PBL-DMM into the learning process. A more in-depth study by involving other variables, such as academic abilities and demographic aspects, at various educational levels should be conducted to further investigate the effects of learning models on students' collaboration skills. The implication of this research for lecturers is that the selection of the right learning model can determine the quality of learning. In addition, the design of activities in the form of group discussions and problem solving can also train students to collaborate.

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REFERENCES

[1] A. Jamaludin and D. Hung, "Problem-solving for STEM learning : navigating games as narrativized problem spaces for 21 st century competencies," *Res. Pract. Technol. Enhanc. Learn.*, vol. 12, pp. 1–14, 2017, doi: 10.1186/s41039-016-0038-0.

[2] N. Ongardwanich, S. Kanjanawasee, and C. Tuipae, "Development of 21st Century Skill Scales as Perceived by Students," *Procedia - Soc. Behav. Sci.*, vol. 191, pp. 737–741, Jun. 2015, doi: 10.1016/j.sbspro.2015.04.716.

[3] N. Pheeraphan, "Enhancement of the 21 st Century Skills for Thai Higher Education by Integration of ICT in Classroom," *Procedia - Soc. Behav. Sci.*, vol. 103, pp. 365–373, 2013, doi: 10.1016/j.sbspro.2013.10.346.

[4] P. T. M. Marope, "Learning and competences for the 21st century," *Prospects*, vol. 44, no. 4, pp. 483–486, Dec. 2014, doi: 10.1007/s11125-014-9333-y.

[5] L. L. Fong, G. K. Sidhu, and C. Y. Fook, "Exploring 21st century skills among postgraduates in Malaysia," *Procedia - Soc. Behav. Sci.*, vol. 123, pp. 130–138, 2014, doi: 10.1016/j.sbspro.2014.01.1406.

[6] L. Greenstein, "Assessing 21st century skills: A guide to evaluating mastery and authentic learning," *Assessing 21st century skills: A guide to evaluating mastery and authentic learning*, no. c. pp. 243-Chapter xvii, 243 Pages, 2012.

[7] D. V. Roekel, "An Educator's Guide to the 'Four Cs,'" p. 3, 2019.

[8] C. D'Agostino, "Collaboration as an Essential School Social Work Skill," *Child. Sch.*, vol. 35, no. 4, pp. 248–251, Oct. 2013, doi: 10.1093/cs/cdt021.

[9] E. R. Lai, "Collaboration : A Literature Review Research Report," *Pearson Publ.*, 2011.

[10] A. Sahin, M. C. Ayar, and T. Adiguzel, "STEM Related After-School Program Activities and Associated Outcomes on Student Learning," *Educ. Sci. Theory Pract.*, vol. 14, no. 1, pp. 309–322, 2014, doi: 10.12738/estp.2014.1.1876.

[11] H. Boholano, "Smart social networking: 21st Century teaching and learning skills," *Res. Pedagog.*, vol. 7, no. 2, pp. 21–29,

2017, doi: 10.17810/2015.45.
[12] J. W. Pellegrino, "Assessment as a positive influence on 21st century teaching and learning: A systems approach to progress.," *Psicol. Educ.*, vol. 20, no. 2, pp. 65–77, 2014, doi: 10.1016/j.pse.2014.11.002.
[13] V. U. Druskat and D. C. Kayes, "Learning versus performance in short-term project teams," *Small Gr. Res.*, vol. 31, no. 3, pp. 328–353, 2000, doi: 10.1177/104649640003100304.
[14] R. O'Leary, Y. Choi, and C. M. Gerard, "The Skill Set of the Successful Collaborator," *Public Adm. Rev.*, vol. 72, no. s1, Nov. 2012, doi: 10.1111/j.1540-6210.2012.02667.x.
[15] J. S. Prichard, R. J. Stratford, and L. A. Bizo, "Team-skills training enhances collaborative learning," *Learn. Instr.*, vol. 16, no. 3, pp. 256–265, 2006, doi: 10.1016/j.learninstruc.2006.03.005.
[16] M. D. Ginsburg-block, C. A. Rohrbeck, and J. W. Fantuzzo, "A Meta-Analytic Review of Social , Self-Concept , and Behavioral Outcomes of Peer-Assisted Learning," *J. Educ. Psychol.*, vol. 98, no. 4, pp. 732–749, 2006, doi: 10.1037/0022-0663.98.4.732.
[17] E. Suprapti and H. Mursyidah, "Development of a Linear Algebra Learning Module with 4Me Stages for Student 4C's Character Development, (Pengembangan Modul Pembelajaran Aljabar Linier dengan Tahapan 4Me untuk Pengembangan Karakter 4C's Mahasiswa)," *MUST J. Math. Educ. Sci. Technol.*, vol. 2, no. 2, pp. 208–220, 2017, doi: 10.30651/must.v2i2.841.
[18] G. Osman, T. M. Duffy, J. Chang, and J. Lee, "Learning through collaboration: student perspectives," *Asia Pacific Educ. Rev.*, vol. 12, no. 4, pp. 547–558, 2011, doi: 10.1007/s12564-011-9156-y.
[19] B. Trilling and C. Fadel, "21 st Century Skills : Learning for life in our times," Jossey-Bass, 2009, pp. 1–243.
[20] R. Keast and M. P. Mandell, "Collaborative competencies/capabilities," *Collaboration Evidence Prevention*. pp. 1–4, 2013.
[21] A. Rohman, "Inter-Teams Game Tournament Learning Model to Develop Collaboration Skills of Teacher Education Students," *J. Penelit. Ilmu Pendidik.*, vol. 6, no. 1, pp. 1–10, 2013.
[22] S. Febrianto, "Peningkatan Kreativitas Dan Kolaborasi Mahasiswa Melalui Pembelajaran Berbasis Proyek Pada Mata Kuliah Pemrograman Di Politeknik Negeri Pontianak," *J. Pendidik. Inform. dan Sains*, vol. 5, no. 2, pp. 195–211, 2016.
[23] E. F. Eshun, P. Osei-Poku, and K. G. de Graft-Johnson, "Schools Pupils ' Perceptions of Factors Impacting on their Creativity Development in Ghana," *J. Educ. Pract.*, vol. 4, no. 1, pp. 144–152, 2013.
[24] G. Sezgin Selçuk, "A Problem-Based Learning scenario that can be used in science teacher education," *Asia-Pacific Forum Sci. Learn. Teach.*, vol. 16, no. 2, pp. 1–26, 2015.
[25] S. S. Purbohadi, H. Harsono, T. Prihatiningsih, and O. Emilia, "Applied CAL on Problem Based Learning Using Gagne's Instructional Design," *Int. J. Emerg. Technol. Learn.*, vol. 9, no. 9, p. 11, Oct. 2014, doi: 10.3991/ijet.v9i9.4116.
[26] E. Ediansyah, D. A. Kurniawan, R. Perdana, and S. Salamah, "Using problem-based learning in college : Mastery concepts subject statistical research and motivation," *Int. J. Eval. Res. Educ.*, vol. 8, no. 3, pp. 446–454, 2019, doi: 10.11591/ijere.v8i3.20243.
[27] J. Hommes, W. De Grave, G. Bos, L. Schuwirth, and A. Scherpbier, "Understanding the effects of time on collaborative learning processes in problem based learning : a mixed methods study," 2014, doi: 10.1007/s10459-013-9487-z.
[28] C. Onyon, "Problem-based learning : a review of the educational and psychological theory," *Clin. Teach.*, vol. 9, no. 1, pp. 22–26, 2012.
[29] Y. Ren and X. Jiang, "A Mind Map Teaching Mode for Sports Anatomy based on 3DBody," *Int. J. Emerg. Technol. Learn.*, vol. 14, no. 10, pp. 4–17, 2019.
[30] M. Davies, "Concept mapping, mind mapping and argument mapping: what are the differences and do they matter?," *High. Educ.*, vol. 62, no. 3, pp. 279–301, 2011, doi: 10.1007/s10734-010-9387-6.
[31] H. Stokhof, B. de Vries, T. Bastiaens, and R. Martens, "Using Mind Maps to Make Student Questioning Effective: Learning Outcomes of a Principle-Based Scenario for Teacher Guidance," *Res. Sci. Educ.*, vol. 50, no. 1, pp. 203–225, 2020, doi: 10.1007/s11165-017-9686-3.
[32] L. Xiao-qiang, Z. Tian-xin, T. Li, R. Jian-jun, L. Bai-yan, and D. Ming, "Online mind-map as interface of electronic resource integration and sharing," *J. Shanghai Jiaotong Univ. (Science*, vol. 20, no. 1, pp. 101–105, 2015, doi: 10.1007/s12204-015-1595-x.
[33] M. Laanpere, E. Matsak, and J. Kippar, "Integrating a concept mapping tool into a virtual learning environment: pedagogical and technological challenges," *Concept maps Theory, Methodol. Technol. Proc. Second Int. Conf. Concept Mapp.*, no. 1, pp. 280–287, 2006.
[34] S. Zaheer, S. M. Butt, G. V. Anatolyevna, and H. Salmani, "Do Mobile Technology in the Classroom Really Improve Learning Outcomes?," *Int. J. Eval. Res. Educ.*, vol. 7, no. 3, pp. 188–193, 2018, doi: 10.11591/ijere.v7.i3.13426.
[35] H. Faste and H. Lin, "The Untapped Promise of Digital Mind Maps," *Proc. SIGCHI Conf. Hum. Factors Comput. Syst.*, pp. 1017–1026, 2012.
[36] M. Noonan, "Mind maps: Enhancing midwifery education," *Nurse Educ. Today*, vol. 33, no. 8, pp. 847–852, 2013, doi: 10.1016/j.nedt.2012.02.003.
[37] N. Hidayati, S. Zubaidah, E. Suarsini, and H. Praherdhiono, "The Integrated PBL-DMM : A Learning Model to Enhance Student Creativity," *Pedagogika*, vol. 135, no. 3, pp. 163–184, 2019.
[38] Pina Tarricone and Joe Luca, "Successful Teamwork: A Case Study," *Proc. 25th HERDSA Annu. Conf. Perth, West. Aust. 7-10 July 2002*, pp. 640–646, 2002.
[39] V. L. Lowell and I. V Ashby, "Supporting the development of collaboration and feedback skills in instructional designers," *J. Comput. High. Educ.*, vol. 30, no. 1, pp. 72–92, 2018, doi: 10.1007/s12528-018-9170-8.
[40] A. Gonzaga, A. J. N. Louw, and S. Van Schalkwyk, "Cognitive and Social Factors In fl uencing Students ' Response and Utilization of Facilitator Feedback in a Problem Based Learning Context," *Heal. Prof. Educ.*, vol. 3, no. 2, pp. 85–98, 2017, doi: 10.1016/j.hpe.2016.09.003.
[41] E. H. J. Yew, E. Chng, and H. G. Schmidt, "Is learning in problem-based learning cumulative?," *Adv. Heal. Sci. Educ.*, vol. 16, no. 4, pp. 449–464, 2011, doi: 10.1007/s10459-010-9267-y.
[42] A. Alrahlah, "How effective the problem-based learning (PBL) in dental education. A critical review," *Saudi Dent. J.*, vol. 28, no. 4, pp. 155–161, 2016, doi: 10.1016/j.sdentj.2016.08.003.
[43] S. M. M. Loyens, P. A. Kirschner, and F. Paas, "Problem-Based Learning." pp. 1–60, 2011.
[44] I. Polyzois, N. Claffey, and N. Mattheos, "Problem-based learning in academic health education. A systematic literature review," *Eur. J. Dent. Educ.*, vol. 14, no. 1, pp. 55–64, 2010, doi: 10.1111/j.1600-0579.2009.00593.x.
[45] C. E. Hmelo-Silver, "Problem-Based Learning: What and How Do Students Learn?," *Educ. Psychol. Rev.*, vol. 16, no. 3, pp. 235–266, 2004.
[46] Y. Lou, P. C. Abrami, and S. D'Apollonia, "Small Group and Individual Learning with Technology: A Meta-Analysis," *Rev.*

Educ. Res., vol. 71, no. 3, pp. 449–521, 2001, [Online]. Available: https://doi.org/10.3102/00346543071003449
[47] J. M. Splichal, J. Oshima, and R. Oshima, "Regulation of collaboration in project-based learning mediated by CSCL scripting reflection," *Comput. Educ.*, vol. 125, no. June, pp. 132–145, 2018, doi: 10.1016/j.compedu.2018.06.003.
[48] I. Taveira-Gomes, R. Mota-Cardoso, and M. Figueiredo-Braga, "Communication skills in medical students – An exploratory study before and after clerkships," *Porto Biomed. J.*, vol. 1, no. 5, pp. 173–180, Nov. 2016, doi: 10.1016/j.pbj.2016.08.002.
[49] F. M. Yusof and H. Halim, "Understanding Teacher Communication Skills," *Procedia - Soc. Behav. Sci.*, vol. 155, no. 2014, pp. 471–476, 2014, doi: 10.1016/j.sbspro.2014.10.324.
[50] H. A. Butler, C. Pentoney, and M. P. Bong, "Predicting Real-World Outcomes: Critical Thinking Ability is a Better Predictor of Life Decisions than Intelligence," *Think. Ski. Creat.*, vol. 25, no. July 2016, pp. 38–46, 2017, doi: 10.1016/j.tsc.2017.06.005.
[51] C. P. Dwyer, M. J. Hogan, and I. Stewart, "An integrated critical thinking framework for the 21st century," *Think. Ski. Creat.*, vol. 12, pp. 43–52, 2014, doi: 10.1016/j.tsc.2013.12.004.

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