

**PENERAPAN *COLLABORATIVE PROJECT BASED LEARNING* (CPBL)
UNTUK MENINGKATKAN *PROBLEM-SOLVING SKILL* DAN
MENGANALISIS PROFIL *COLLABORATIVE SKILL* PESERTA DIDIK
SMA PADA MATERI LISTRIK DINAMIS**

TESIS

**Diajukan untuk memenuhi sebagian syarat untuk memperoleh gelar
Magister Pendidikan Program Studi Pendidikan Fisika**



Oleh:

ENDRI LESMANA SIDIK

2105456

**PROGRAM STUDI MAGISTER PENDIDIKAN FISIKA
FAKULTAS PENDIDIKAN MATEMATIKA DAN ILMU PENGETAHUAN ALAM
UNIVERSITAS PENDIDIKAN INDONESIA**

2025

PENERAPAN *COLLABORATIVE PROJECT BASED LEARNING* (CPBL)
UNTUK MENINGKATKAN *PROBLEM-SOLVING SKILL* DAN
MENGANALISIS PROFIL *COLLABORATIVE SKILL* PESERTA DIDIK SMA
PADA MATERI LISTRIK DINAMIS

Oleh
Endri Lesmana Sidik

S.Pd Universitas Islam Negeri Sunan Gunung Djati Bandung, 2016

Sebuah Tesis yang diajukan untuk memenuhi salah satu syarat memperoleh gelar
Magister Pendidikan (M.Pd) pada Fakultas Pendidikan Matematika dan Ilmu
Pengetahuan Alam

© Endri Lesmana Sidik 2025
Universitas Pendidikan Indonesia
Agustus 2025

Hak Cipta dilindungi undang-undang.
Tesis ini tidak boleh diperbanyak seluruhnya atau sebagian,
dengan dicetak ulang, difotokopi, atau cara lainnya tanpa ijin dari penulis.

LEMBAR PENGESAHAN

**PENERAPAN *COLLABORATIVE PROJECT BASED LEARNING* (CPBL)
UNTUK MENINGKATKAN *PROBLEM-SOLVING SKILL* DAN
MENGANALISIS PROFIL *COLLABORATIVE SKILL* PESERTA DIDIK
SMA PADA MATERI LISTRIK DINAMIS**

Disusun oleh:

Endri Lesmana Sidik
2105456

Disetujui dan disahkan oleh:

Pembimbing I



Dr. Achmad Samsudin, M.Pd.
NIP. 198310072008121004

Pembimbing II



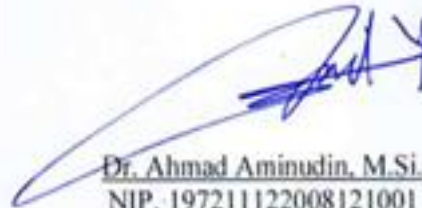
Irma Rahma Suwarma, S.Si., M.Pd., Ph.D.
NIP. 198105032008012015

Penguji



Lina Aviyanti, S.Pd., M.Si., Ph.D.
NIP. 197705012001122001

Penguji



Dr. Ahmad Aminudin, M.Si.
NIP. 197211122008121001

Mengetahui,

Ketua Program Studi Sarjana dan Magister Pendidikan Fisika



Dr. Achmad Samsudin, M.Pd.
NIP. 198310072008121004

**PENERAPAN *COLLABORATIVE PROJECT BASED LEARNING* (CPBL)
UNTUK MENINGKATKAN *PROBLEM-SOLVING SKILL* DAN
MENGANALISIS PROFIL *COLLABORATIVE SKILL* PESERTA DIDIK
SMA PADA MATERI LISTRIK DINAMIS**

Endri Lesmana Sidik
2105456

Pembimbing I : Dr. Achmad Samsudin, M.Pd.
Pembimbing II : Irma Rahma Suwarma, S.Si., M.Pd., Ph.D.

ABSTRAK

Listrik dinamis merupakan topik penting yang erat kaitannya dengan kehidupan sehari-hari. Namun, pentingnya topik ini belum selaras dengan tingkat keterampilan siswa SMA dalam memecahkan masalah terhadap topik tersebut. Keadaan ini didukung oleh fakta bahwa beberapa siswa SMA masih saling mengandalkan dalam kegiatan kolaborasi pada pembelajaran di sekolah. Penelitian ini bertujuan untuk menganalisis peningkatan *Problem-Solving Skill* dan profil *Collaborative Skill* siswa SMA. Metode yang digunakan adalah *mixed methods* dengan desain *Embedded Experimental Model* dengan *Pre-test – Post-test Control Group*. Sampel penelitian ini merupakan siswa kelas XI dari salah satu SMA di Kabupaten Subang. Sampel terdiri atas kelas eksperimen dan kontrol yang berjumlah sama yaitu 33 siswa. Penelitian ini menggunakan instrumen tes *Problem-Solving Skill* berbentuk uraian, lembar observasi *Collaborative Skill*, dan penilaian respons siswa. Analisis peningkatan *Problem-Solving Skill* untuk kedua kelas menggunakan Rasch model dengan melihat perbedaan rata-rata peningkatan nilai *logit pre-test* dan *post-test* pada *person measure* dan melihat perbedaan *N-Gain* yang diperoleh menggunakan SPSS, analisis *Collaborative Skill* untuk kedua kelas juga menggunakan Rasch model dengan melihat perbedaan rata-rata nilai *logit* pada *person measure*, dan penilaian respons siswa membantu untuk melihat tanggapan terhadap pembelajaran CPBL. Hasil penelitian menunjukkan peningkatan *Problem-Solving Skill* rata-rata peningkatan nilai *logit* kelas eksperimen sebesar 4,05 dan kelas kontrol sebesar 3,96, dan *N-Gain* rata-rata untuk kelas eksperimen sebesar 0,78 (kategori tinggi) dan *N-Gain* rata-rata untuk kelas kontrol sebesar 0,68 (kategori sedang). Peningkatan *Problem-Solving Skill* sama-sama dialami oleh kedua kelas. Apabila dibandingkan, CPBL lebih efektif untuk meningkatkan *Problem-Solving Skill* siswa mengenai Listrik dinamis daripada PjBL. Selain itu, siswa kelas eksperimen memiliki profil *Collaborative Skill* yang lebih baik daripada siswa kelas kontrol.

Kata kunci: *Collaborative Project Based Learning, Collaborative and Problem-Solving Skills, Listrik dinamis, embedded mixed methods.*

**IMPLEMENTATION OF COLLABORATIVE PROJECT BASED
LEARNING (CPBL) TO IMPROVE PROBLEM-SOLVING SKILL AND
ANALYZE THE COLLABORATIVE SKILL PROFILE OF SENIOR HIGH
SCHOOL STUDENTS ON THE TOPIC OF DYNAMIC ELECTRICITY**

Endri Lesmana Sidik
2105456

1st Supervisor : Dr. Achmad Samsudin, M.Pd.
2nd Supervisor : Irma Rahma Suwarma, S.Si., M.Pd., Ph.D.
Magister of Physics Education Study Program FPMIPA UPI

ABSTRACT

Ohm's Law and types of electrical circuits is an important topic closely related to everyday life. However, the importance of this topic is not yet aligned with the level of high school students' problem-solving skills in this area. This condition is supported by the fact that some high school students still rely on each other during collaborative learning activities at school. This study aims to analyze the improvement of high school students' Problem-Solving Skill and Collaborative skill profile. The method used is a mixed methods approach with an Embedded Experimental Model with a Pre-test - Post-test Control Group Design. The research sample consisted of 11th grade students from a high school in Subang Regency, with 33 students each in the experimental and control classes. The study uses a Problem-Solving Skill instrument in the form of essays, direct observation of Collaborative Skill, and student response assessment. The improvement in Problem-Solving Skills for both classes was analyzed using the Rasch model by comparing the average increase in logit scores from the pre-test and post-test person measures and examining the differences in N-Gain scores using SPSS. Collaborative Skill analysis for both classes also used the Rasch model, comparing the average logit scores in the person measures. Additionally, student responses to the learning process were assessed to evaluate the effectiveness of CPBL. The results showed an average logit score increase in Problem-Solving Skills of 4.05 for the experimental class and 3.96 for the control class. The average N-Gain for the experimental class was 0.78 (high category), while the control class had an average N-Gain of 0.68 (medium category). Both classes experienced improvements in Problem-Solving Skills. However, when compared, CPBL proved to be more effective in enhancing students' Problem-Solving Skills on the topic of Ohm's Law and types of electrical circuits than PjBL. Additionally, students in the experimental class have a better collaborative skill profile than those in the control class.

Keywords: Collaborative Project Based Learning, Collaborative and Problem-Solving Skills, Ohm's Law and types of electrical circuits, embedded mixed methods.

KATA PENGANTAR

Assalamu'alaikum Wr. Wb.

Puji dan Syukur penulis panjatkan ke hadirat Allah SWT atas segala limpahan Rahmat-Nya sehingga penulis dapat menyelesaikan tesis yang berjudul “Penerapan *Collaborative Project Based Learning* (CPBL) untuk Meningkatkan *Problem-Solving Skill* dan Menganalisis Profil *Collaborative Skill* Peserta didik SMA pada Materi Listrik Dinamis”. Sebagai salah satu syarat memperoleh gelar Magister Pendidikan Fisika (M.Pd) pada Program Studi Pendidikan Fisika di Universitas Pendidikan Indonesia. Selama proses penyusunan tesis ini, penulis telah mendapatkan banyak dukungan, bimbingan, dan motivasi dari berbagai pihak. Oleh karena itu pada kesempatan ini penulis menyampaikan ucapan terima kasih dan penghargaan setulus-tulusnya kepada:

1. Bapak Dr. Achmad Samsudin, M.Pd., selaku dosen Pembimbing I yang telah memberikan motivasi secara intensif selama penyusunan tesis.
2. Ibu Irma Rahma Suwarma, S.Si., M.Pd., Ph.D., selaku dosen Pembimbing II yang turut memberikan masukan dan koreksi yang sangat berarti dalam penyempurnaan tesis ini.
3. Keluarga tercinta, orang tua, serta sahabat-sahabat yang senantiasa memberikan do'a, semangat, dan dukungan moral maupun material selama proses studi dan penyusunan tesis ini.
4. Semua pihak yang tidak dapat penulis sebutkan satu per satu, yang telah membantu dalam pelaksanaan penelitian dan penyusunan tesis ini.

Penulis menyadari bahwa tesis ini masih jauh dari kesempurnaan. Oleh karena itu, penulis mengharapkan kritik dan saran yang membangun untuk penyempurnaan karya ini. Semoga tesis ini dapat memberikan manfaat bagi pembaca dan pihak-pihak yang berkepentingan dalam bidang Pendidikan.

Bandung, 20 Agustus 2025

Penulis

DAFTAR ISI

ABSTRAK	iii
ABSTRACT	iv
KATA PENGANTAR.....	v
DAFTAR ISI.....	vi
DAFTAR TABEL	viii
DAFTAR GAMBAR	x
DAFTAR GRAFIK	xii
DAFTAR LAMPIRAN	xiii
BAB I PENDAHULUAN.....	1
1.1 Latar Belakang	1
1.2 Rumusan Masalah	9
1.3 Tujuan Penelitian.....	9
1.4 Hipotesis Penelitian.....	9
1.5 Manfaat Penelitian	10
1.6 Definisi Operasional.....	10
1.7 Struktur Organisasi Tesis	13
BAB II KAJIAN PUSTAKA	14
2.1 <i>Project Based Learning (PjBL) and Collaborative Project Based Learning (CPBL)</i>	14
2.2 <i>Collaborative Skill</i>	19
2.3 <i>Problem-Solving Skill</i>	20
2.4 Konsep Listrik Dinamis	22
2.5 Keterkaitan antara <i>Collaborative Project Based Learning</i> dengan <i>Collaborative and Problem-Solving Skills</i>	33
2.6 Kerangka Pikir Penelitian	34

BAB III METODE PENELITIAN	37
3.1 Desain Penelitian.....	37
3.2 Populasi dan Sampel	39
3.3 Instrumen Penelitian.....	39
3.4 Analisis Instrumen Penelitian	42
3.5 Prosedur Penelitian.....	47
3.6 Analisis Data	49
BAB IV HASIL PENELITIAN	61
4.1 Karakteristik <i>Collaborative Project Based Learning</i>	61
4.2 Profil <i>Collaborative Skill</i> Peserta didik.....	73
4.3 Peningkatan <i>Problem-Solving Skill</i> Peserta didik.....	82
4.4 Respons Peserta didik Terhadap Pembelajaran.....	92
4.5 Efektivitas Peningkatan <i>Problem-Solving Skills</i> Peserta didik.....	100
BAB V PEMBAHASAN	105
5.1 Karakteristik <i>Collaborative Project Based Learning</i>	105
5.2 Profil <i>Collaborative Skill</i> Peserta didik.....	111
5.3 Peningkatan <i>Problem-Solving Skill</i> Peserta didik	120
5.4 Respons Peserta didik Terhadap Pembelajaran	127
5.5 Efektivitas Peningkatan <i>Problem-Solving Skills</i> Peserta didik.....	131
BAB VI SIMPULAN, IMPLIKASI, DAN REKOMENDASI.....	134
6.1 Simpulan	134
6.2 Implikasi.....	135
6.3 Rekomendasi.....	135
DAFTAR PUSTAKA.....	136

DAFTAR TABEL

Tabel 2.1 Aspek <i>Problem-Solving Skill</i>	22
Tabel 2.2 Karakteristik Pelajaran Fisika.....	23
Tabel 2.3 Capaian Pembelajaran Fisika Fase F	23
Tabel 2.4 Kode Warna Resistor	27
Tabel 2.5 Representasi Perbedaan Rangkaian Seri dan Paralel.....	31
Tabel 2.6 Keterkaitan antara Tahapan Model <i>Collaborative Project Based Learning</i> dengan aspek <i>Collaborative and Problem-Solving Skills</i>	34
Tabel 3.1 Rubrik Penilaian <i>Collaborative Skill</i> pada Elemen <i>Participation</i>	40
Tabel 3.2 Penilaian Respons Peserta didik	41
Tabel 3.3 Teknik Pengumpulan Data.....	42
Tabel 3.4 Sebaran Kisi-kisi Konstruksi Soal <i>Problem-Solving Skill</i>	42
Tabel 3.5 Hasil Uji Validitas Konten	44
Tabel 3.6 Ketentuan Analisis Validitas pada <i>Winstep 5.4.1</i>	44
Tabel 3.7 Interpretasi dari MNSQ, ZSTD, dan PT Measure-All Corr	44
Tabel 3.8 Hasil Uji Validitas Konstruk	45
Tabel 3.9 Ketentuan Nilai <i>Person reliability</i> dan <i>item reliability</i>	46
Tabel 3.10 Ketentuan Nilai <i>Crombach Alpha</i> (α).....	46
Tabel 3.11 Hasil Analisis Reliabilitas <i>Problem-Solving Skill</i>	46
Tabel 3.12 Rubrik Penilaian <i>Problem-Solving Skill</i>	50
Tabel 3.13 Interpretasi <i>N-Gain Score</i>	52
Tabel 3.14 Penilaian Respons Peserta didik	52
Tabel 3.15 Kriteria Respons Peserta didik.....	53
Tabel 3.16 Interpretasi Hasil Uji <i>Effect Size Cohen's d</i>	58
Tabel 3.17 Interpretasi Hasil Uji <i>Effect Size r</i>	60
Tabel 3.18 Interpretasi <i>N-Gain Percent</i>	60
Tabel 4.1 Keterlaksanaan Tahapan Pembelajaran	61
Tabel 4.2 Bentuk Instrumen Tes <i>Problem-Solving Skill</i>	71
Tabel 4.3 Hasil Validasi Instrumen Tes <i>Problem-Solving Skill</i> Menurut Lima Ahli	72

Tabel 4.4 Perbandingan Nilai <i>Logit Person Measure Collaborative Skill</i>	73
Tabel 4.5 Distribusi Frekuensi <i>Collaborative Skill</i> Kode <i>EC</i>	74
Tabel 4.6 Kategori dan Frekuensi <i>Collaborative Skill</i> Kode <i>EC</i>	75
Tabel 4.7 Distribusi Frekuensi <i>Collaborative Skill</i> Kode <i>CC</i>	76
Tabel 4.8 Kategori dan Frekuensi <i>Collaborative Skill</i> Kode <i>CC</i>	76
Tabel 4.9 Persentase <i>Collaborative Skill</i> pada Elemen <i>Participation</i>	78
Tabel 4.10 Nilai Rata-rata <i>Collaborative Skill</i> pada Elemen <i>Participation</i>	80
Tabel 4.11 Perbandingan Nilai <i>Logit Person Measure Problem-Solving Skill</i>	83
Tabel 4.12 Interpretasi Peningkatan <i>Problem-Solving Skill EC</i>	84
Tabel 4.13 Distribusi dan Interpretasi Peningkatan <i>Problem-Solving Skill EC</i>	84
Tabel 4.14 Rekapitulasi Interpretasi Peningkatan <i>Problem-Solving Skill EC</i>	85
Tabel 4.15 Interpretasi Peningkatan <i>Problem-Solving Skill CC</i>	86
Tabel 4.16 Distribusi dan Interpretasi Peningkatan <i>Problem-Solving Skill CC</i>	86
Tabel 4.17 Rekapitulasi Interpretasi Peningkatan <i>Problem-Solving Skill CC</i>	87
Tabel 4.18 Hasil Perhitungan <i>N-Gain Score</i> Menyeluruh	89
Tabel 4.19 Hasil Perhitungan <i>N-Gain Score</i> Setiap Aspek dan Butir Soal.....	90
Tabel 4.20 Rekapitulasi Penilaian Respons Peserta didik	93
Tabel 4.21 Rekapitulasi Persentase Penilaian Respons Peserta didik Setiap Pernyataan (P)	94
Tabel 4.22 Kelompok Tema Kesan Pembelajaran pada Kelas Eksperimen	97
Tabel 4.23 Kelompok Tema Kesan Pembelajaran pada Kelas Kontrol	99
Tabel 4.24 Hasil Konversi <i>N-Gain Percent</i>	104

DAFTAR GAMBAR

Gambar 2.1 <i>Project Based Learning Design</i>	17
Gambar 2.2 <i>Collaborative Project Based Learning Design</i>	18
Gambar 2.3 Penghantar yang Menghubungkan Dua Benda Berbeda Potensial...25	
Gambar 2.4 Rangkaian Listrik Sederhana.....	26
Gambar 2.5 Representasi Gambar Hambatan atau Resistor.....	27
Gambar 2.6 Cincin Warna Resistor	27
Gambar 2.7 Arus Masuk dan Keluar Percabangan.....	28
Gambar 2.8 Representasi Gambar Sumber Tegangan	28
Gambar 2.9 Rangkaian Seri.....	29
Gambar 2.10 Rangkaian Paralel	30
Gambar 2.11 Alur Penyelesaian Masalah Nyata	31
Gambar 2.12 Kerangka Pikir Penelitian	36
Gambar 3.1 Skema <i>Mixed Methods Embedded Experimental Model Design</i>	37
Gambar 3.2 <i>Pre-test – Post-test Control Group Design</i>	38
Gambar 3.3 Prosedur Penelitian <i>Collaborative Project Based Learning</i>	48
Gambar 4.1 Persiapan Peserta didik	62
Gambar 4.2 Penyampaian Substansi Materi.....	62
Gambar 4.3 Peserta didik Menelaah isi LKPD.....	63
Gambar 4.4 Observer Memosisikan Diri pada Kelompok yang Sudah Ditentukan	63
Gambar 4.5 Keterlaksanaan Tahap <i>Problem Recollection</i>	64
Gambar 4.6 Keterlaksanaan Tahap <i>Problem Acknowledgement</i>	64
Gambar 4.7 Keterlaksanaan Tahap <i>Solution Map Out</i>	65
Gambar 4.8 Keterlaksanaan Tahap <i>Apply the Solution</i> – Desain dan Mengukur....	65
Gambar 4.9 Keterlaksanaan Tahap <i>Apply the Solution</i> – Membangun Kerangka dan Instalasi Listrik.....	66
Gambar 4.10 Keterlaksanaan Tahap <i>Apply the Solution</i> – Memodifikasi Coding ..	66
Gambar 4.11 Keterlaksanaan Tahap <i>Evaluate the Solution</i>	67
Gambar 4.12 Keterlaksanaan Tahap <i>Current Problem</i>	67
Gambar 4.13 Apresiasi, Refleksi, Penguatan, dan Informasi	68

Gambar 4.14 <i>Student Collaboration</i>	68
Gambar 4.15 Peran Guru Sebagai Fasilitator dan Mediator dalam CPBL	69
Gambar 4.16 LKPD Berisi Tantangan.....	70
Gambar 4.17 Hasil LKPD Sesuai Sintak CPBL dan Bersifat Reflektif	70
Gambar 4.18 Data Hasil Uji Normalitas Shapiro-Wilk.....	101
Gambar 4.19 Data Hasil Uji Homogenitas Bartlett.....	102
Gambar 4.20 Hasil Uji-t Tidak Berpasangan.....	103
Gambar 4.21 <i>Output T-Test Group Statistic</i>	103

DAFTAR GRAFIK

Grafik 1.1 Hasil Penelitian <i>Problem-Solving Skill</i> Terdahulu.....	4
Grafik 1.2 Hasil Penelitian <i>Collaborative Skill</i> Terdahulu	5
Grafik 1.3 Hasil Studi Pendahuluan <i>Problem-Solving Skill</i>	5
Grafik 1.4 Hasil Studi Pendahuluan <i>Collaborative Skill</i>	6
Grafik 4.1 Perbandingan Rata-rata Nilai <i>Logit Collaborative Skill</i>	77
Grafik 4.2 Profil <i>Collaborative Skill</i> Peserta didik pada Aspek <i>Action</i>	79
Grafik 4.3 Profil <i>Collaborative Skill</i> Peserta didik pada Aspek <i>Interaction</i>	79
Grafik 4.4 Profil <i>Collaborative Skill</i> Peserta didik pada Aspek <i>Task Completion</i>	80
Grafik 4.5 Perbandingan Nilai Rata-rata <i>Collaborative Skill</i> setiap Aspek.....	81
Grafik 4.6 Peningkatan Rata-rata Nilai <i>Logit Problem-Solving Skill</i>	88
Grafik 4.7 Perbandingan <i>N-Gain Score Problem-Solving Skill</i> setiap Aspek dan Butir Soal....	92
Grafik 4.8 Persentase Respons Peserta didik terhadap Pilihan Jawaban Sangat Setuju.....	96
Grafik 4.9 Persentase Respons Peserta didik terhadap Pilihan Jawaban Setuju.....	96

DAFTAR LAMPIRAN

LAMPIRAN A : Modul Ajar, Instrumen Tes, dan Instrumen Non-Tes

1. Modul Ajar <i>Home Electrical Installation</i>	145
2. Modul Ajar <i>Traffic Light Project</i>	165
3. Lembar Observasi <i>Collabrative Skill</i>	181
4. Soal <i>Pre-test – Post-test Problem-Solving Skill</i>	196
5. Penilaian Respons Peserta didik	200

LAMPIRAN B : Penilaian Modul Ajar dan Instrumen

1. Penilaian Modul Ajar	202
2. Penilaian Instrumen Observasi <i>Collaborative Skill</i>	208
3. Penilaian Instrumen <i>Problem-Solving Skill</i>	211
4. Penilaian Instrumen Respons Peserta didik	321

LAMPIRAN C : Data Hasil Penelitian

1. Data Observasi <i>Collaborative Skill</i>	324
2. Data <i>Pre-test</i>	326
3. Data <i>Post-test</i>	328
4. Data Penilaian Respons Peserta didik	330
5. Data Survei Kesan Pembelajaran	334

LAMPIRAN D : Ethical Clearance dan Sampel Data Penelitian

1. Lembar Pernyataan <i>Ethical Clearance</i>	339
2. Sampel LKPD Kelas Eksperimen dan Kelas Kontrol	340
3. Sampel <i>Collaborative</i> Kelas Eksperimen dan Kelas Kontrol	348
4. Sampel <i>Pre-test</i> Kelas Eksperimen dan Kelas Kontrol	354
5. Sampel <i>Post-test</i> Kelas Eksperimen dan Kelas Kontrol	356
6. Sampel Penilaian Respons Kelas Eksperimen dan Kelas Kontrol	360
7. Sampel Dokumentasi Projek Kelas Eksperimen dan Kelas Kontrol	366

DAFTAR PUSTAKA

- Ahmad, F., & Khan, R. A. (2015). A power comparison of various normality tests. *Pakistan Journal of Statistics and Operation Research*, 331-345.
- Amalia, G. R., Kurniasih, S., Jaenudin, D. (2022). Project-Based Learning on Biotechnology Materials to Enhance High School Students' Creativity and Problem-Solving Skills. *Journal of Science Education and Practice*. 6(1).
- Amini, R. (2021). Penerapan project-based learning dalam meningkatkan keterampilan kolaborasi siswa pada pembelajaran IPA di sekolah dasar. *Jurnal Basicedu*, 5(4), 2417-2424.
- Ardithayasa, I. W., Gading, I. K., Widiana, I. W. (2022). Project Based Learning Modules to Improve Scientific Literacy and Problem-Solving Skill. *Journal for Lesson and Learning Studies*. 5(2), 316-325.
- Aronson, E., & Patnoe, S. (1997). *The Jigsaw Classroom: Building Coopeation in The Classroom* (2nd ed.). New York: Longman.
- Astuti, P. W., & Hermawan, D. (2021). Penerapan Model Project Based Learning untuk Meningkatkan Motivasi dan Hasil Belajar Siswa. *Jurnal Pendidikan*, 12(1), 45-52.
- Bell, S. (2010). Project-based learning for the 21st century: Skills for the future. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, 83(2), 39–43. <https://doi.org/10.1080/00098650903505415>.
- Bybee, R. W. (2013). *The Case for STEM Education*. National Science Teacher Association. NSTA Press.
- Bahar, A., & June Maker, C. (2015). Cognitive backgrounds of problem solving: A comparison of open-ended vs. closed mathematics problems. *Eurasia Journal of Mathematics, Science and Technology Education*, 11(6), 1531–1546. <https://doi.org/10.12973/eurasia.2015.1410a>.
- Binkley, M. E. (2012). *Defining twenty-first century skills*. London: Springer.
- Bond, T. G., Yan, Z., & Heene, M. (2020). Applying the rasch model: Fundamental measurement in the human sciences. In *Applying the Rasch Model: Fundamental Measurement in* <https://doi.org/10.4324/9780429030499>

- Boone, W. J., & Staver, J. R. (2020). Correction to: Advances in Rasch Analyses in the Human Sciences. In *Advances in Rasch Analyses in the Human Sciences*. https://doi.org/10.1007/978-3-030-43420-5_21
- Boyaci, S. D., & Atalay, N. (2016). A Scale Development for 21st Century Skills of Primary School Students. *International Journal of Intruction*. 9(1).
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101. <https://doi.org/10.1191/1478088706qp063oa>
- Clark, R. C., & Mayer, R. E. (2016). *E-learning and the science of instruction: Proven guidelines for consumers and designers of multimedia learning*. 4th ed.
- Clavert, M. (2017). *Industri 4.0 Implications for Higher Order Institutions*. Retrieved July 5, 2020, from https://universitiesofthefuture.eu/wp-content/uploads/2019/02/State-of-Maturity_Report.pdf.
- Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.
- Cohen, E. G. (1994). Restructuring the classroom: Conditions for productive small groups. *Review of Educational Research*, 64, 1–35.
- Corlu, M. S., & Capraro, M. R. (2014). Implication for Educating Our Teachers For the Age of Innovation. *Education and Science*. 39(171).
- Damayanti, D., & Anitah, S. (2019). Penerapan Project Based Learning untuk Meningkatkan Keaktifan dan Kreativitas Belajar Siswa. *Jurnal Inovasi Pendidikan IPA*, 5(2), 114-121.
- Doctor, J. L., Dornfeld, J., Frodermann, E., Heller, K., Hsu, L., Jackson, K. A., Mason, A., Ryan, Q. X., Yang, J. (2016) Assessing student written problem solutions: A problem-solving rubric with application to introductory physics. *American Physics Society*.
- Fahmi, A., & Harjito. (2021). Analisis Collaborative Problem Solving pada Penerapan Model Pre-Laboratory Berbasis Blended Learning. *Journal of Chemistry in Education* 10(1). Universitas Negeri Semarang.
- Fatmawati, A. (2017). Pengaruh model pembelajaran berbasis proyek terhadap kemampuan pemecahan masalah dan hasil belajar siswa pada materi fluida dinamis. *Jurnal Pendidikan Fisika Indonesia*, 13(1). 1-8.

- Fiore, S. M., Graesser, A., Greiff, S., Griffin, P., Gong, B., Kyllonen, P., Massey, C., O'Neil, H., Pellegrino, J., Rothman, R., Soulé, H., & Davier, A. Von. (2013). Collaborative problem solving. In *Instructional-Design Theories and Models: A New Paradigm of Instructional Theory (Vol. 2)*. <https://doi.org/10.4324/9781410603784-17>.
- Fujita, T., Doney, J., Flanagan, R., & Wegerif, R. (2019). *Collaborative group work in mathematics in the UK and Japan: use of group thinking measure tests*. Education 3- 13 :1–15.
- Glass, G. V., McGaw, B., & Smith, M. L. (1981). *Meta-analysis in social research*. SAGE Publications.
- Graesser, A., Kuo, B.-C., & Liao, C.-H. (2017). Complex Problem Solving in Assessments of Collaborative Problem Solving. *Journal of Intelligence*, 5(2), 10. <https://doi.org/10.3390/jintelligence5020010>.
- Gravetter, F. J., & Wallnau, L. B. (2014). *Statistics for the behavioral sciences* (9th ed.). Wadsworth, Cengage Learning.
- Griffin, P., & Care, E. (2014). *Developing learners' collaborative problem-solving skills*. http://vp-learningdiaries.weebly.com/uploads/9/4/9/8/9498170/developing_learners_collaborative_problem_solving_p_griffin.pdf.
- Gok, T. (2008). Effects of problem-solving strategies teaching on the problem-solving attitude of cooperative learning group in physics education. *Journal of Theory and Practice in Education*, 4(2), 253-266.
- Guo, P., Saab, N., Post, L. S., Admiraal, W. (2020). A review of project-based learning in higher education: Student outcomes and measures. *International Journal of Education Research*.
- Hattie, J. (2009) *Visible Learning: A Synthesis of Over 800 Meta-Analyses Relating to Achievement*. London: Routledge.
- Hauben, M. (2018). A visual aid for teaching the Mann–Whitney U formula. *Teaching Statistics*, 40(2), 60-63.
- Heeren, T., & D'Agostino, R. (1987). Robustness of the two independent samples t-test when applied to ordinal scaled data. *Statistics in medicine*, 6(1), 79-90.
- Helle, L., Tynjälä, P., & Olkinuora, E. (2006). Project-based learning in post-secondary education – Theory, practice and rubber sling shots. *Higher Education*, 51(2), 287–314. <https://doi.org/10.1007/s10734-004-6386-5>.

- Hernawati, D., & Komariah, A. (2020). Project-Based Learning dalam meningkatkan keterampilan pemecahan masalah dan kolaborasi siswa SMP. *JUPI* 6(2), 213-223.
- Hesse, F., Care, E., Buder, J., Sassenberg, K., & Griffin, P. (2015). A framework for teachable collaborative problem-solving skills. In P. Griffin & E. Care (Eds.), *Assessment and teaching of 21st century skills: Methods and approach* (pp. 37–56). Dordrecht: Springer.
- Hikmah, N.H., & Siswono, T.Y.E. (2020). Profil *Collaborative Problem Solving* Siswa Kelas IX dalam Memecahkan Masalah. *Jurnal Pendidikan Indonesia (Vol. 4 Issue 2)*. Jurnal Cendikia.
- Honey, M., Pearson, G., & Schweingruber, H. (2014). STEM Integration in K-12 Education. In *STEM Integration in K-12 Education*. <https://doi.org/10.17226/18612>.
- Howell, D. C. (2011). *Fundamental Statistics for the Behavioral Sciences*, Seventh Edition. Wadsworth: Cengage Learning.
- Huang, W., London, J. S., Perry, L. A. (2023). Project-Based Learning Promotes Students' Perceived Relevance in an Engineering Statistics Course: A Comparison of Learning in Synchronous and Online Learning Environments. *Journal of Statistics and Data Science Education*. 31(2), 179-187.
- Hujjatusnaini, N., Corebima, A. D., Prawiro, S. R., Gofur, A. (2022). The Effect of Blended Project-Based Learning Integrated With 21st-Century Skills on Pre-Service Biology Teachers' Higher-Order Thinking Skills. *Jurnal Pendidikan IPA Indonesia*. 11(1), 104-118.
- Keast, R., & Mandell, M. P. (2013). *Collaborative Competencies/Capabilities*. Canberra: Australian Research Alliance for Children and Youth.
- Kementerian Pendidikan dan Kebudayaan Republik Indonesia. (2020). Peraturan Menteri Pendidikan dan Kebudayaan Nomor 22 Tahun 2020 tentang Rencana Strategis Kementerian Pendidikan dan Kebudayaan Tahun 2020–2024. Jakarta: Kementerian Pendidikan dan Kebudayaan.
- Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi. (2022). *Keputusan Kepala Badan Standar, Kurikulum, dan Asesmen Pendidikan Nomor 033/H/KR/2022 tentang Perubahan atas Keputusan Kepala BSKAP Nomor 008/H/KR/2022 tentang Capaian Pembelajaran pada PAUD, Pendidikan Dasar, dan Menengah pada Kurikulum Merdeka*. Jakarta: Kemendikbudristek

- Klein, C., DeRouin, R. E., & Salas, E. (2006). Uncovering Workplace Interpersonal Skills: A Review, Framework, and Research Agenda. *International Review of Industrial and Organizational Psychology*, 79-126. <https://doi.org/10.1002/9780470696378.ch3>.
- Kraft, M. A. (2020). Interpreting effect sizes interventions. *Educational Researcher*, 49(4), 241-253
- Krajcik, J. S., & Shin, N. (2014). Project-based learning. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences (2nd ed., pp. 275–297)*. Cambridge University Press. <https://doi.org/10.1017/CBO9781139519526.018>
- Krajcik, J., Schneider, B., Miller, E. A., Chen, I., Bradford, L., Baker, Q., Brtz, K., Miller, C., Li, T., Codere, S., Brown, D. P. (2022). Assessing the Effect of Project-Based Learning on Science Learning in Elementary Schools. *American Educational Research Journal*, 20(10), 1-33.
- Kurnianto, A., Sunjaya, D. K., Rinawan, F. R., & Hilmanto, D. (2023). Validation and Reliability of Lifestyle Instruments for Indonesian Adolescents with Hypertension Family History: A Rasch Model. *Open Access Macedonian Journal of Medical Sciences*, 11(B), 109-114.
- Kusuma, R. D., & Purnomo, P. (2020). Peningkatan keterampilan kolaboratif melalui project-based learning dalam pembelajaran matematika. *Aksioma*, 9(2), 378-387.
- Lai, E., DiCerbo, K., & Foltz, P. (2017). Skills for Today: Collaboration. In *Executive Development* (Vol. 3, Issue 4).
- Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. New York: Cambridge University Press.
- Lee, H., & Lee, K. (2018). The effects of project-based learning on students' collaboration and communication skills in science education. *Asia-Pacific Science Education*, 4(1), 1-15.
- Lee, J., & Lee, Y. (2018). The effects of project-based learning on students' collaboration and communication skills: A meta-analysis. *International Journal of Educational Research*, 92, 1–12. <https://doi.org/10.1016/j.ijer.2018.07.005>
- Lestari. (2016). Penerapan Pembelajaran Kooperatif Tipe Group Investigation Berbantuan Proyek Terhadap Kemampuan Pemecahan Masalah Matematis Siswa SMP. *Jurnal Matematika dan Pendidikan Matematika*, 1(2), 154-165.

- Lim, T. S., & Loh, W. Y. (1996). A comparison of tests of equality of variances. *Computational Statistics & Data Analysis*, 22(3), 287-301.
- Linacre, J. M. (2018). A user's guide to Winstep mini step Rasch-Model computer programs. Beaverton, OR: Winsteps.
- MacFarland, T. W., Yates, J. M., MacFarland, T. W., & Yates, J. M. (2016). Mann whitney u test. *Introduction to nonparametric statistics for the biological sciences using R*, 103-132.
- Markula, A., & Aksela, M. (2022). The key characteristics of project-based learning: how teachers implement projects in K-12 science education. *Disciplinary and Interdisciplinary Science Education Research*, 4(2), 1. <https://doi.org/10.1186/s43031-021-00042-x>.
- Maslow, A. H. (1943). A theory of human motivation. *Psychological Review*, 50(4), 370-396.
- McKnight, P. E., & Najab, J. (2010). Mann-Whitney U Test. *The Corsini encyclopedia of psychology*, 1-1.
- Mergendoller, J. R., Maxwell, N. L., & Bellisimo, Y. (2006). The effectiveness of problem-based instruction: A comparative study of instructional methods and student characteristics. *Interdisciplinary Journal of Problem-Based Learning*, 1(2). <https://doi.org/10.7771/1541-5015.1026>
- Moog, J., Saw, L.G., Hashim, R. *et al.* The triple alliance: how a plant-ant, living in an ant-plant, acquires the third partner, a scale insect. *Insectes Soc.* 52, 169–176 (2005). <https://doi.org/10.1007/s00040-005-0791-3>.
- Ningsih, H. N, T., Rahmawati, Y., Ridwan, A. (2017). Development 21st century skills in chemistry classrooms: Opportunities and Challenges of STEAM Intergration. AIP Conference Proceedings. <https://doi.org/10.1063/1.4995107>.
- Nissen, J. M., Talbot, R. M., Thompson, A. N., & Van Dusen, B. (2018). Comparison of normalized gain and Cohen's d for analyzing gains on concept inventories. *Physical Review Physics Education Research*, 14(1), 010115.
- Novitassari, R., & Yulianti, D. (2017). Pengaruh model project-based learning terhadap keterampilan kolaborasi dan hasil belajar IPA siswa. *Unnes Science Education Journal*, 6 (2), 1836-1843.
- Nurzakiyah, E. (2021) Model Pembelajaran Learning Cycle 7E dengan Pendekatan STEM (Science, Technology, Engineering, and Mathematics) untuk

Meningkatkan Kemampuan Pemecahan Masalah dan Kolaborasi Siswa. Universitas Pendidikan Indonesia.

- Odoi, B., Twumasi-Ankrah, S., Samita, S., & Al-Hassan, S. (2022). The Efficiency of Bartlett's Test using Different forms of Residuals for Testing Homogeneity of Variance in Single and Factorial Experiments-A Simulation Study. *Scientific African*, e01323/
- OECD. (2010). PISA 2012 *Field Trial Problem Solving Framework*. Retrieved July 5, 2020, from <https://www.oecd.org/pisa/pisaproducts/46962005.pdf>.
- OECD. (2016). *Chapter 4 tables: How skills are used in the workplace*. <https://doi.org/10.1787/9789264258051-table78-en>.
- OECD. (2017). PISA 2015 collaborative problem-solving framework july 2017 1. *Journal of the Learning Sciences*, 2(2), 1–5. <https://doi.org/10.1080/02602930802691572>.
- OECD. (2018). The Future of Education and Skills: Education 2030. *OECD Education Policy Perspectives*, No. 98. OECD Publishing. <https://doi.org/10.1787/54ac7020-en>.
- Polya, G. (1971). *How To Solve It: A New Aspect of Mathematical Method*. Princeton, New Jersey: Princeton University Press.
- Putri, W. N., & Amin, M. (2015). Pengaruh model pembelajaran berbasis proyek terhadap keterampilan berpikir kritis dan pemecahan masalah. *Jurnal Pendidikan Biologi Indonesia*, 1(2), 124-133.
- Ralph, R. A. (2015). Post secondary project-based learning in science, technology, engineering and mathematics. *Journal of Technology and Science Education*, 6(1), 26–35. <https://doi.org/10.3926/jotse.155>.
- Redhana. (2015). Menyiapkan Lulusan FMIPA yang Menguasai Keterampilan abad XXI. *Semnas FMIPA Undiksha V, Optimalisasi Peran MIPA dalam Membangun SDM Indonesia yang Kompetitif*.
- Reis, A. C. B., Barbalho, S. C. M., & Zanette, A. C. D. (2017). A bibliometric and classification study of Project-based Learning in Engineering Education. *Production*, 27(spe), e20162258. <https://doi.org/10.1590/0103-6513.225816>.
- Rochon, J., Gondan, M., & Kieser, M. (2012). To test or not to test: Preliminary assessment of normality when comparing two independent samples. *BMC medical research methodology*, 12(1), 1-11.

- Rosli, R., Abdullah, M., Siregar, N. C., Hamid, N. S. A., Abdullah, S., Beng, G. K., ... & Bais, B. (2020). Student Awareness of Space Science: Rasch Model Analysis for Validity and Reliability. *World Journal of Education*, 10(3), 170-177.
- Saputra, R., & Amelia, R. (2020). Respons Peserta Didik terhadap Penerapan Model PjBL dalam Pembelajaran IPA. *Jurnal Pendidikan Sains*, 8(1), 35-42.
- Sari, R. M., & Zulaikha, S. (2021). Penerapan Project-Based Learning untuk meningkatkan kemampuan problem solving siswa pada materi energi. *Jurnal Pendidikan Sains Indonesia*, 9(2), 261-270.
- Sears, D., & Reagin, J. (2013). Individual versus Collaborative Problem Solving: Divergent Outcomes Depending on Task Complexity. *Instructional Science: An International Journal of the Learning Science*, 1153-1172.
- Shapiro, S. S., & Wilk, M. B. (1965). An analysis of variance test for normality (complete samples). *Biometrika*, 52(3/4), 591-611. <https://doi.org/10.1093/biomet/52.3-4.591>
- Stasser, G., & Vaughan, S. I. (1996). Models of participation during face-to-face unstructured discussion. In E. H. Witte & J. H. Davis (Eds.), *Understanding group behavior: Consensual action by small groups* (Vol. 1, pp. 165-192). Mahwah: Erlbaum.
- Sulistyawati, D., & Suryatmi, Y. (2019). Penerapan model Project Based-Learning untuk meningkatkan kemampuan pemecahan masalah dan hasil belajar siswa. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, 8(2), 233-243.
- Sumintono, B., & Widhiarso, W. (2015). Aplikasi pemodelan Rasch pada assessment pendidikan. <http://eprints.um.edu.my/id/eprint/14228>
- Sundayana, R. (2020). *Statistika Penelitian Pendidikan*. Bandung: Alfabeta.
- Trilling, B., & Fadel, C. (2009). 21st Century Skills_ Learning for Life in Our Times. In *Journal of Sustainable Development Education and Research* (Vol. 2, Issue 1). Jossey-Bass.
- UNESCO. (2017). Education for Sustainable Development Goals: *Learning Objectives*. UNESCO Publishing. ISBN 978-92-3-100209-0. Diakses dari <http://unesdoc.unesco.org/images/0024/002474/247444e.pdf>
- Utami, A. P., & Dewanto. (2017). Kemampuan komunikasi, kolaborasi, metakognisi, dan hasil belajar mata Pelajaran teknologi mekanik siswa kelas x pada penerapan pendekatan saintifik smkn 1 kediri. *Jurnal Pendidikan Teknik Mesin*, 17-26.

- Vasquez, J. A., Sneider, C., & Comer, M. (2013). Lesson Essentials, Grades 3–8 Integrating Science, TEchnology, Engineering, and Mathematics. HEINEMANN.
- Vygotsky, L. S. (1978). Mind in Society: The development of higher psychological processes. Cambridge, MA: Harvard University Press.
- Vorapongsathorn, T., Taejaroenkul, S., & Viwatwongkasem, C. (2004). A comparison of type I error and power of Bartlett's test, Levene's test and Cochran's test under violation of assumptions. *Songklanakarin J. Sci. Technol*, 26(4), 537-547.
- Wulandari, D., & Widodo, A. (2018). Project Based Learning sebagai Upaya Meningkatkan Keterlibatan Emosional Siswa dalam Pembelajaran Fisika. *Jurnal Pendidikan Fisika Indonesia*, 14(2), 56-63.
- Zhao, Y., & Wang, L. (2022). A case study of student development across project-based learning units in middle school chemistry. *Disciplinary and Interdisciplinary Science Education Research*. 4(5), 1.