

**PEMBELAJARAN PROYEK STEM-ESD TERKAIT SDG *LIFE BELOW*
WATER TERHADAP KETERAMPILAN REKAYASA DAN AKSI SISWA
DALAM MENGATASI PERMASALAHAN MIKROPLASTIK**

SKRIPSI

*Disusun untuk memenuhi sebagian syarat untuk memperoleh gelar Sarjana
Pendidikan Biologi*



Oleh:

Qisthina Hunafa Qudsi

NIM 2104667

**PROGRAM STUDI PENDIDIKAN BIOLOGI
FAKULTAS PENDIDIKAN MATEMATIKA DAN ILMU PENGETAHUAN
ALAM
UNIVERSITAS PENDIDIKAN INDONESIA
2025**

**PEMBELAJARAN PROYEK STEM-ESD TERKAIT SDG *LIFE BELOW*
WATER TERHADAP KETERAMPILAN REKAYASA DAN AKSI SISWA
DALAM MENGATASI PERMASALAHAN MIKROPLASTIK**

Oleh
Qisthina Hunafa Qudsi

Sebuah skripsi yang diajukan untuk memenuhi salah satu syarat memperoleh gelar
Sarjana Pendidikan pada Fakultas Pendidikan Matematika dan Ilmu Pengetahuan
Alam

© Qisthina Hunafa Qudsi 2025
Universitas Pendidikan Indonesia
Agustus 2025

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

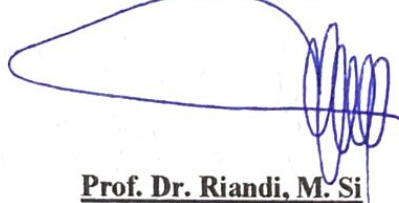
LEMBAR PENGESAHAN
PEMBELAJARAN PROYEK STEM-ESD TERKAIT SDG *LIFE BELOW*
***WATER* TERHADAP KETERAMPILAN REKAYASA DAN AKSI SISWA**
DALAM MENGATASI PERMASALAHAN MIKROPLASTIK

QISTHINA HUNafa QUDSI

NIM 2104667

Disetujui dan disahkan oleh:

Pembimbing I,



Prof. Dr. Riandi, M. Si

NIP. 196305011988031002

Pembimbing II,



Prof. Dr. Phil. Ari Widodo, M. Ed.

NIP. 196705271992031001

Mengetahui,

Ketua Program Studi Pendidikan Biologi



Dr. Kusnadi, M. Si.

NIP. 196805091994031001

ABSTRAK

Pembelajaran Proyek STEM – ESD Terkait SDG *Life Below Water* terhadap Keterampilan Rekayasa dan Aksi Siswa dalam Mengatasi Permasalahan Mikroplastik

**Qisthina Hunafa Qudsi
2104667**

Ekosistem perairan tawar di Indonesia semakin terancam oleh polusi plastik, khususnya mikroplastik, yang menjadi tantangan dalam pencapaian SDG 14 *Life Below Water*. Dibutuhkan pembelajaran bermuatan SDGs yang melibatkan siswa SMA dalam mengatasi permasalahan mikroplastik. Penelitian ini bertujuan untuk mendapatkan informasi mengenai pembelajaran proyek STEM-ESD terkait SDG *Life below Water* terhadap keterampilan rekayasa dan peningkatan aksi siswa dalam mengatasi permasalahan mikroplastik. Metode dan desain penelitian yang digunakan dalam penelitian ini adalah *pre-experiment one group pretest posttest design*. Pengambilan data keterampilan rekayasa menggunakan LKPD, produk teknologi, dan proses siswa dalam merekayasa teknologi penyaring mikroplastik sederhana yang kemudian diolah menggunakan rubrik PBER (*Performance-Based Evaluation Rubric*) dan aksi siswa menggunakan kuesioner aksi berkelanjutan. Hasil menunjukkan bahwa pembelajaran proyek STEM-ESD berhasil memunculkan keterampilan rekayasa siswa pada kategori *novice designer* dengan nilai rata-rata keseluruhan kelompok sebesar 71 namun peningkatan aksi siswa berdasarkan skor *N-Gain* hanya sebesar 0,042 yang dinilai sangat rendah. Penerapan pembelajaran proyek STEM-ESD ini mampu memberikan dampak positif terhadap keterampilan rekayasa dan aksi siswa dalam mendukung prinsip dan nilai-nilai berkelanjutan SDGs. Rekomendasi penelitian selanjutnya adalah keterampilan rekayasa difokuskan melalui *scaffolding*, fasilitasi desain, dan manajemen proyek, sedangkan aksi siswa diperkuat melalui durasi reflektif yang lebih panjang dan menekankan pada isu lokal.

Kata kunci: Pembelajaran Proyek STEM-ESD, SDG *Life below Water*, Keterampilan Rekayasa Siswa, Aksi Berkelanjutan Siswa, Mikroplastik

ABSTRACT

STEM – ESD Project-Based Learning on SDG Life below Water to Enhance Student’s Engineering Design Skill and Sustainability Action in Addressing Microplastic Issues

Qisthina Hunafa Qudsi
2104667

Freshwater ecosystems in Indonesia are increasingly threatened by plastic pollution, particularly microplastics, which pose a challenge to achieving SDG 14 Life below Water. There is a need for SDG-oriented learning that engages high school students in addressing microplastic problems. This study aims to investigate the implementation of STEM-ESD project-based learning related to SDG Life below Water on student’s engineering skills and the improvement of their sustainable actions in tackling microplastic issues. The research employed a pre-experimental one group pretest posttest design. Data on engineering skills were collected through LKPD, student’s engineered products, and their processes in designing a simple microplastic filter, which were then analyzed using the Performance-Based Evaluation Rubric (PBER). Student’s sustainable actions were measured using a sustainable action questionnaire. The results showed that the STEM-ESD project-based learning successfully fostered students’ engineering skills at the novice designer category with an overall average score of 71. However, the increase in students’ actions based on the N-Gain score was only 0.042, which is considered very low. The application of STEM-ESD project-based learning had a positive impact on student’s engineering skills and sustainable actions in supporting the principles and values of the SDGs. Future research is recommended to strengthen engineering skills through scaffolding, design facilitation, and project management, while sustainable actions should be enhanced through longer reflective durations and a stronger emphasis on local issues.

Keywords: STEM-ESD Project-Based Learning, SDG Life below Water, Student’s Engineering Design Skill, Student’s Sustainability Action, Microplastic

DAFTAR ISI

KATA PENGANTAR	i
UCAPAN TERIMA KASIH.....	ii
ABSTRAK	vi
ABSTRACT	vii
DAFTAR ISI.....	viii
DAFTAR TABEL.....	xii
DAFTAR GAMBAR	xiv
DAFTAR LAMPIRAN	xvii
BAB I PENDAHULUAN	1
1.1 Latar Belakang	1
1.2 Rumusan Masalah	7
1.3 Tujuan Penelitian.....	8
1.4 Manfaat Penelitian.....	8
1.5 Batasan Penelitian	9
1.6 Asumsi Penelitian.....	9
1.7 Hipotesis Penelitian.....	9
1.8 Struktur Organisasi Skripsi	10
BAB II PEMBELAJARAN PROYEK STEM-ESD TERKAIT SDG LIFE BELOW WATER, KETERAMPILAN REKAYASA SISWA, AKSI SISWA, DAN TEKNOLOGI PENYARING MIKROPLASTIK.....	12
2.1 Pembelajaran Proyek STEM - ESD Terkait SDG <i>Life below Water</i>	12
2.2 Keterampilan Rekayasa Siswa Terkait SDG <i>Life below Water</i>	21
2.2.1 Fase Masalah.....	23
2.2.2 Fase Solusi	23

2.2.3 Fase Implementasi	24
2.2.4 Fase Manajemen Proses.....	24
2.3 Aksi Siswa Terkait SDG <i>Life below Water</i>	25
BAB III METODE PENELITIAN.....	30
3.1 Metode dan Desain Penelitian	30
3.1.1 Metode Penelitian	30
3.1.2 Desain Penelitian	31
3.2 Populasi dan Sampel	31
3.3 Definisi Operasional.....	32
3.4 Instrumen Penelitian.....	35
3.4.1 Instrumen Keterampilan Rekayasa	35
3.4.2 Instrumen Aksi.....	41
3.4.3 Instrumen Tambahan	47
3.5 Prosedur Penelitian.....	48
3.5.1 Tahap Persiapan.....	48
3.5.2 Tahap Pengumpulan Data.....	49
3.5.3 Tahap Pengolahan dan Analisis Data	55
3.5.4 Penginterpretasian, Pembahasan, dan Penarikan Kesimpulan.....	55
3.6 Analisis Data	56
3.6.1 Analisis Data Keterampilan Rekayasa Siswa	56
3.6.2 Analisis Data Aksi Siswa.....	57
3.7 Alur Penelitian.....	58
BAB IV TEMUAN DAN PEMBAHASAN	60
4.1 Keterampilan Rekayasa Siswa Terkait Teknologi Penyaring Mikroplastik dalam Mencapai SDG <i>Life below Water</i>	60

4.1.1 Mengidentifikasi Permasalahan Mikroplastik	66
4.1.2 Menyebutkan Penyebab dan Dampak Permasalahan Mikroplastik.....	75
4.1.3 Merumuskan Rencana Penanggulangan	80
4.1.4 Menganalisis Kekurangan dari Solusi Teknologi Alat Penyaring Mikroplastik yang Ada	83
4.1.5 Memikirkan Solusi untuk Menyelesaikan Kekurangan dari Alat Penyaring Mikroplastik yang Ada	87
4.1.6 Mengeksplorasi dan Mempertimbangkan Ukuran Pipa.....	92
4.1.7 Mengeksplorasi dan Mempertimbangkan Ide Bentuk Alat	94
4.1.8 Mempertimbangkan dan Mempertimbangkan berbagai Alternatif Bahan	97
4.1.9 Menyusun RAB	100
4.1.10 Merancang Mekanisme Kerja Alat	103
4.1.11 Mempertimbangkan Fungsionalitas Alat.....	106
4.1.12 Mempertimbangkan Orisinalitas.....	110
4.1.13 Mengembangkan Ide menjadi Desain.....	115
4.1.14 Merealisasikan Desain menjadi Prototipe.....	121
4.1.15 Menguji Coba Prototipe.....	128
4.1.16 Memperhitungkan Nilai Ekonomi	132
4.1.17 Menganalisis Dampak Alat terhadap Lingkungan.....	135
4.1.18 Mengevaluasi dan Meningkatkan Efisien Alat.....	140
4.1.19 Keterampilan Komunikasi Presentasi	147
4.1.20 Penulisan Laporan.....	149
4.1.21 Evaluasi Kemampuan Kolaboratif Siswa	150
4.1.22 Pengumpulan Laporan	151
4.2 Hasil Data Aksi Siswa Terkait SDG <i>Life below Water</i>	153

4.2.1 Hasil Perhitungan Uji <i>N-Gain</i> Aksi Terkait SDG <i>Life below Water</i> ..	156
4.2.2 Pola Perubahan Nilai Aksi dan Rencana Aksi.....	158
4.2.3 <i>N-Gain</i> Aksi Siswa pada Tindakan Masa Lalu Terkait SDG <i>Life below Water</i>	162
4.2.4 <i>N-Gain</i> Aksi Siswa pada Tindakan Masa Sekarang Terkait SDG <i>Life below Water</i>	165
4.2.5 <i>N-Gain</i> Aksi Siswa pada Rencana Tindakan Masa Depan Terkait SDG <i>Life below Water</i>	168
4.2.6 <i>N-Gain</i> Capaian Kompetensi Siswa Aksi Terkait SDG <i>Life below Water</i>	170
BAB V SIMPULAN, IMPLIKASI, DAN REKOMENDASI	174
5.1 Simpulan.....	174
5.2 Implikasi	174
5.3 Rekomendasi	175
Daftar Pustaka	176
LAMPIRAN	186
RIWAYAT HIDUP PENULIS	xviii

DAFTAR TABEL

Tabel 2.1 Model Pembelajaran STEM.....	16
Tabel 2.2 ESD Learning Goals SDG 14 <i>Life below Water</i>	26
Tabel 3.1 Desain Penelitian <i>One Group Pretest-Posttest</i>	31
Tabel 3.2 Instrumen Penelitian Pembelajaran Proyek STEM-ESD Terkait SDG <i>Life below Water</i> dalam Mengatasi Permasalahan Mikroplastik	35
Tabel 3.3 Kisi-Kisi Instrumen Keterampilan Rekayasa Siswa dalam Pembelajaran Proyek STEM-ESD Terkait SDG <i>Life below Water</i> dalam Mengatasi Permasalahan Mikroplastik	37
Tabel 3.4 Kisi-Kisi Instrumen Aksi Siswa Terkait SDG <i>Life below Water</i> Sebelum Uji Validitas dan Reliabilitas	42
Tabel 3.5 Hasil Pengujian Uji Validitas dan Reliabilitas Instrumen Aksi SDG <i>Life below Water</i> Tindakan per Masa.....	43
Tabel 3.6 Hasil Uji Validitas dan Reliabilitas Instrumen Aksi SDG <i>Life below Water</i> Capaian Kompetensi	45
Tabel 3.7 Hasil Pengujian Uji Validitas dan Reliabilitas Instrumen Aksi SDG <i>Life below Water</i> Tindakan per Masa (Instrumen Tambahan yang Kurang).....	46
Tabel 3.8 Kisi-Kisi Instrumen Aksi Siswa Terkait SDG <i>Life below Water</i> Setelah Uji Validitas dan Reliabilitas	46
Tabel 3.9 Kisi-Kisi Instrumen Wawancara.....	47
Tabel 3.10 Deskripsi Prosedur Tahapan Pelaksanaan Kegiatan Pembelajaran Proyek STEM-ESD Terkait SDG <i>Life below Water</i>	49
Tabel 3.11 Kategori Penilaian Keterampilan Rekayasa per Fase	57
Tabel 3.12 Kategori Penilaian Keterampilan Rekayasa Secara Keseluruhan.....	57
Tabel 3.13 Interpretasi skor <i>N-Gain</i>	58
Tabel 4.1 Hasil Penilaian Keterampilan Rekayasa Siswa Setiap Kelompok Berdasarkan <i>Performance-Based Evaluation Rubric</i> (PBER).....	62
Tabel 4.2 Jawaban LKPD tiap Kelompok Terkait Identifikasi Permasalahan Mikroplastik.....	68
Tabel 4.3 Jawaban LKPD tiap Kelompok Terkait Penyebab dan Dampak Permasalahan Mikroplastik.....	77
Tabel 4.4 Jawaban LKPD tiap Kelompok Terkait Merumuskan Rencana Penanggulangan Mikroplastik.....	81
Tabel 4.5 Jawaban LKPD tiap Kelompok Terkait Menganalisis Kekurangan dari Solusi Teknologi Alat Penyaring Mikroplastik yang Ada	85
Tabel 4.6 Jawaban LKPD tiap Kelompok Terkait Memikirkan Solusi untuk Menyelesaikan Kekurangan dari Alat Penyaring Mikroplastik yang Ada	88
Tabel 4.7 Jawaban LKPD tiap Kelompok Terkait Pertimbangan Fungsionalitas Alat	107
Tabel 4.8 Jawaban LKPD tiap Kelompok Terkait Pertimbangan Orisinalitas ...	112
Tabel 4.9 Jawaban LKPD tiap Kelompok Terkait Mengembangkan Ide menjadi Desain.....	117
Tabel 4.10 Hasil Desain dan Prototipe Alat Penyaring Mikroplastik yang Dibuat oleh Setiap Kelompok.....	123

Tabel 4.11 Jawaban LKPD tiap Kelompok Terkait Perhitungan Nilai Ekonomi Alat	133
Tabel 4.12 Jawaban LKPD tiap Kelompok Terkait Analisis Dampak Lingkungan	137
Tabel 4.13 Jawaban LKPD tiap Kelompok Terkait Evaluasi dan Pengembangan Efisien Alat.....	141
Tabel 4.14 Analisis Statistik Deskriptif Aksi Siswa Terkait SDG <i>Life below Water</i> pada Pembelajaran Proyek STEM-ESD.....	154
Tabel 4.15 Analisis Statistik Deskriptif <i>N-Gain Pretest</i> dan <i>Posttest</i> Aksi Siswa terkait SDG <i>Life below Water</i> pada Pembelajaran Proyek STEM-ESD.....	157
Tabel 4.16 <i>N-Gain</i> Aksi pada Tindakan Masa Lalu	163
Tabel 4.17 <i>N-Gain</i> Aksi pada Tindakan Masa Sekarang.....	167
Tabel 4.18 <i>N-Gain</i> Aksi pada Rencana Tindakan Masa Depan	169
Tabel 4.19 <i>N-Gain</i> Aksi pada Capaian Kompetensi	172

DAFTAR GAMBAR

Gambar 2.1 Mikroplastik pada Lingkungan Perairan	18
Gambar 2.2 Alat Penyaring Mikroplastik Berbasis <i>Bulk Acoustic Wave</i> (BAW) 20	
Gambar 2.3 Rangkaian Alat Penyaring Mikroplastik Berbasis <i>Bulk Acoustic Wave</i> (BAW).....	21
Gambar 3.1 Alur Penelitian.....	59
Gambar 4.1 Persentase Ketercapaian Indikator Mengidentifikasi Permasalahan Mikroplastik	67
Gambar 4.2 Persentase Ketercapaian Indikator Menyebutkan Penyebab dan Dampak Permasalahan Mikroplastik	76
Gambar 4.3 Persentase Ketercapaian Indikator Merumuskan Rencana Penanggulangan	80
Gambar 4.4 Persentase Ketercapaian Indikator Menganalisis Kekurangan dari Solusi Teknologi Alat Penyaring Mikroplastik yang Ada	84
Gambar 4.5 Persentase Ketercapaian Indikator Memikirkan Solusi untuk Menyelesaikan Kekurangan dari Alat Penyaring Mikroplastik yang Ada	88
Gambar 4.6 Persentase Ketercapaian Indikator Mengeksplorasi dan Mempertimbangkan Ukuran Pipa	92
Gambar 4.7 Persentase Ketercapaian Indikator Mengeksplorasi dan Mempertimbangkan Ide Bentuk Alat.....	95
Gambar 4.8 Contoh Bentuk Alat Kelompok 2A (Bentuk Optimal) dan Bentuk Alat Kelompok 5A (Kurang Optimal)	97
Gambar 4.9 Persentase Ketercapaian Indikator Mengeksplorasi dan Mempertimbangkan berbagai Alternatif Bahan.....	98
Gambar 4.10 Contoh Jawaban LKPD Terkait Pertimbangan berbagai Alternatif Bahan dengan Kelompok 3B (Nilai Rendah) dan Bentuk Alat Kelompok 2A (Nilai Tinggi).....	100
Gambar 4.11 Persentase Ketercapaian Indikator Menyusun RAB	101
Gambar 4.12 Contoh Jawaban LKPD Terkait Penyusunan RAB Kelompok 6A (Nilai Rendah) dan Kelompok 1B (Nilai Tinggi)	102
Gambar 4.13 Persentase Ketercapaian Indikator Merancang Mekanisme Kerja Alat	104
Gambar 4.14 Contoh Jawaban LKPD Terkait Merancang Mekanisme Kerja Kelompok 2B (Nilai Rendah) dan Kelompok 6A (Nilai Tinggi)	105
Gambar 4.15 Persentase Ketercapaian Indikator Mempertimbangkan Fungsionalitas Alat	107
Gambar 4.16 Persentase Ketercapaian Indikator Mempertimbangkan Orisinalitas	111
Gambar 4.17 Persentase Ketercapaian Indikator Mengembangkan Ide menjadi Desain.....	116
Gambar 4.18 Desain Alat Kelompok 1A	117
Gambar 4.19 Desain Alat Kelompok 2A	117
Gambar 4.20 Desain Alat Kelompok 3A	117
Gambar 4.21 Desain Alat Kelompok 4A	118
Gambar 4.22 Desain Alat Kelompok 5A	118

Gambar 4.23 Desain Alat Kelompok 6A	118
Gambar 4.24 Desain Alat Kelompok 1B	119
Gambar 4.25 Desain Alat Kelompok 2B	119
Gambar 4.26 Desain Alat Kelompok 3B	119
Gambar 4.27 Desain Alat Kelompok 4B	120
Gambar 4.28 Desain Alat Kelompok 5B	120
Gambar 4.29 Desain Alat Kelompok 6B	120
Gambar 4.30 Persentase Ketercapaian Indikator Merealisasikan Desain menjadi Prototipe	122
Gambar 4.31 Prototipe Penyaring Mikroplastik 1A	123
Gambar 4.32 Prototipe Penyaring Mikroplastik 2A	123
Gambar 4.33 Prototipe Penyaring Mikroplastik 3A	123
Gambar 4.34 Prototipe Penyaring Mikroplastik 4A	124
Gambar 4.35 Prototipe Penyaring Mikroplastik 5A	124
Gambar 4.36 Prototipe Penyaring Mikroplastik 6A	124
Gambar 4.37 Prototipe Penyaring Mikroplastik 1B.....	124
Gambar 4.38 Prototipe Penyaring Mikroplastik 2B.....	125
Gambar 4.39 Prototipe Penyaring Mikroplastik 3B.....	125
Gambar 4.40 Prototipe Penyaring Mikroplastik 4B.....	125
Gambar 4.41 Prototipe Penyaring Mikroplastik 5B.....	126
Gambar 4.42 Prototipe Penyaring Mikroplastik 6B.....	126
Gambar 4.43 Persentase Ketercapaian Indikator Menguji Coba Prototipe.....	128
Gambar 4.44 Kelompok Hasil Penyaringan Kategori Air Bersih tanpa Mikroplastik dan Residu Filter	130
Gambar 4.45 Kelompok Hasil Penyaringan Kategori Air Bersih tanpa Mikroplastik tetapi Terdapat Residu Filter.....	131
Gambar 4.46 Kelompok Hasil Penyaringan Kategori Air Mengandung Mikroplastik dan/atau Residu Filter.....	132
Gambar 4.47 Persentase Ketercapaian Indikator Memperhitungkan Nilai Ekonomi Alat.....	133
Gambar 4.48 Persentase Ketercapaian Indikator Menganalisis Dampak Alat terhadap Lingkungan.....	136
Gambar 4.49 Persentase Ketercapaian Indikator Mengevaluasi dan Mengembangkan Efisien Alat.....	140
Gambar 4.50 Redesain Kelompok 1A	141
Gambar 4.51 Redesain Kelompok 2A	141
Gambar 4.52 Redesain Kelompok 3A	142
Gambar 4.53 Redesain Kelompok 4A	142
Gambar 4.54 Redesain Kelompok 5A	142
Gambar 4.55 Redesain Kelompok 6A	143
Gambar 4.56 Redesain Kelompok 1B.....	143
Gambar 4.57 Redesain Kelompok 2B.....	144
Gambar 4.58 Redesain Kelompok 3B.....	144
Gambar 4.59 Redesain Kelompok 4B.....	144
Gambar 4.60 Redesain Kelompok 5B.....	145
Gambar 4.61 Redesain Kelompok 6B.....	145

Gambar 4.62 Persentase Ketercapaian Indikator Keterampilan Komunikasi Presentasi	148
Gambar 4.63 Persentase Ketercapaian Indikator Penulisan Laporan	149
Gambar 4.64 Persentase Ketercapaian Indikator Evaluasi Kemampuan Kolaboratif Siswa	150
Gambar 4.65 Persentase Ketercapaian Indikator Pengumpulan Laporan.....	152
Gambar 4.66 Persentase Perubahan Nilai Aksi dan Rencana Aksi per Individu Siswa	159
Gambar 4.67 Rata-Rata Nilai <i>Pretest</i> dan <i>Posttest</i> Aksi Siswa pada Tindakan Masa Lalu	163
Gambar 4.68 Distribusi Kategori Hasil Perhitungan Uji <i>N-Gain</i> Aksi Siswa pada Tindakan Masa Lalu.....	163
Gambar 4.69 Rata-Rata Nilai <i>Pretest</i> dan <i>Posttest</i> Aksi Siswa pada Tindakan Masa Sekarang.....	166
Gambar 4.70 Distribusi Kategori Hasil Perhitungan Uji <i>N-Gain</i> Aksi Siswa pada Tindakan Masa Sekarang	166
Gambar 4.71 Rata-Rata Nilai <i>Pretest</i> dan <i>Posttest</i> Aksi Siswa pada Rencana Tindakan Masa Depan.....	168
Gambar 4.72 Distribusi Kategori Hasil Perhitungan Uji <i>N-Gain</i> Aksi Siswa pada Rencana Tindakan Masa Depan.....	169
Gambar 4.73 Rata-Rata Nilai <i>Pretest</i> dan <i>Posttest</i> Capaian Kompetensi.....	171
Gambar 4.74 Distribusi Kategori Hasil Perhitungan Uji <i>N-Gain</i> Capaian Kompetensi Aksi Siswa	172

DAFTAR LAMPIRAN

A.1 Instrumen Aksi Siswa.....	188
A.2 Modul Pembelajaran Proyek STEM-ESD Terkait SDG <i>Life below Water</i> .	190
B.1 Tabulasi Data <i>Pretest</i> Aksi Siswa	208
B.2 Tabulasi Data <i>Posttest</i> Aksi Siswa.....	218
B.3 Lembar Kerja Peserta Didik (LKPD).....	227
C.1 Hasil Uji Validitas dan Reliabilitas Instrumen Aksi	233
C.2 Hasil Uji Deskriptif Data Aksi Siswa Secara Umum.....	238
C.3 Hasil Uji <i>N-Gain (Normalized Gain)</i> Data Aksi Siswa Secara Umum.....	238
C.4 Hasil Uji <i>N-Gain (Normalized Gain)</i> Data Aksi Siswa per Indikator (Masa Lalu).....	239
C.5 Hasil Uji <i>N-Gain (Normalized Gain)</i> Data Aksi Siswa per Indikator (Masa Sekarang).....	241
C.6 Hasil Uji <i>N-Gain (Normalized Gain)</i> Data Aksi Siswa per Indikator (Masa Depan).....	244
C.7 Hasil Uji <i>N-Gain (Normalized Gain)</i> Data Aksi Siswa per Indikator (Capaian Kompetensi)	247
C.8 Pola Perubahan Nilai Aksi dan Rencana Aksi Siswa.....	250
D.1 Surat Izin Penelitian	252
D.2 Surat Telah Menyelesaikan Penelitian	252
D.3 Dokumentasi Kegiatan	253

Daftar Pustaka

- Abella, R. J., Daschbach, J. M., & McNichols, R. J. (1994). Reverse engineering industrial applications. *Computers and Industrial Engineering*, 26(2), 381–385. [https://doi.org/10.1016/0360-8352\(94\)90071-X](https://doi.org/10.1016/0360-8352(94)90071-X)
- Al-Balushi, S. M., & Al-Aamri, S. S. (2014). The effect of environmental science projects on student's environmental knowledge and science attitudes. *International Research in Geographical and Environmental Education*, 23(3), 213–227. <https://doi.org/10.1080/10382046.2014.927167>
- Ardoin, N. M., Bowers, A. W., Roth, N. W., & Holthuis, N. (2018). Environmental education and K-12 student outcomes: A review and analysis of research. *Journal of Environmental Education*, 49(1), 1–17. <https://doi.org/10.1080/00958964.2017.1366155>
- Arora, N. K., Mishra, I., & Arora, P. (2023). SDG 14: life below water- viable oceans necessary for a sustainable planet. *Environmental Sustainability*, 6(4), 433–439. <https://doi.org/10.1007/s42398-023-00299-0>
- Arthur, C., Baker, J., & Bamford, H. (2009). Proceedings of the International Research Workshop on the Occurrence , Effects , and Fate of Microplastic Marine Debris. *Group, September 9-11*, 1–49.
- Atman, C. J. (2019). Design timelines : Concrete and sticky representations of design process expertise. *Design Studies*, 65, 125–151. <https://doi.org/10.1016/j.destud.2019.10.004>
- Auta, H. S., Emenike, C. U., & Fauziah, S. H. (2017). Distribution and importance of microplastics in the marine environment : A review of the sources , fate , effects , and potential solutions. *Environmental International*, 102, 165–176.
- Bangay, C., & Blum, N. (2010). Education responses to climate change and quality: Two parts of the same agenda? *International Journal of Educational Development*, 30(4), 359–368. <https://doi.org/10.1016/j.ijedudev.2009.11.011>
- Barron, B. J. S., Schwartz, D. L., Vye, N. J., Moore, A., Petrosino, A., Zech, L., & Bransford, J. D. (1998). Doing with Understanding: Lessons from Research on Problem- and Project-Based Learning. *Journal of the Learning Sciences*, 7(3–4), 271–311. <https://doi.org/10.1080/10508406.1998.9672056>
- Blumenfeld, P., Fishman, B. J., Krajcik, J., Marx, R. W., & Soloway, E. (2000). Creating usable innovations in systemic reform: Scaling up technology-embedded project-based science in urban schools. *Educational Psychologist*, 35(3), 149–164. https://doi.org/10.1207/S15326985EP3503_2
- Bramwell-Lalor, S., Kelly, K., Ferguson, T., Hordatt Gentles, C., & Roofe, C. (2020). Project-based Learning for Environmental Sustainability Action. *Southern African Journal of Environmental Education*, 36, 57–72. <https://doi.org/10.4314/sajee.v36i1.10>

- Breiner, J. M., Harkness, S. S., Johnson, C. C., & Koehler, C. M. (2012). What Is STEM? A Discussion About Conceptions of STEM in Education and Partnerships. *School Science and Mathematics*, 112(1), 3–11. <https://doi.org/10.1111/j.1949-8594.2011.00109.x>
- Browne, M. A., Crump, P., Niven, S. J., Teuten, E., Tonkin, A., Galloway, T., & Thompson, R. (2011). Accumulation of microplastic on shorelines worldwide: Sources and sinks. *Environmental Science and Technology*, 45(21), 9175–9179. <https://doi.org/10.1021/es201811s>
- Bruun Jensen, B. (2000). Health knowledge and health education in the democratic health-promoting school. *Health Education*, 100(4), 146–154. <https://doi.org/10.1108/09654280010330900>
- Bybee, R. W. (2013). *The Case for STEM Education: Challenges and Opportunities*. NSTA Press.
- Chao, Y. L., & Lam, S. P. (2009). Measuring Responsible Environmental Behavior: Self-Reported and Other-Reported Measures and Their Differences in Testing a Behavioral Model. *Environment and Behavior*, 43(1), 53–71. <https://doi.org/10.1177/0013916509350849>
- Charyton, C., Jagacinski, R. J., Merrill, J. A., Clifton, W., & Dedios, S. (2011). Assessing creativity specific to engineering with the revised Creative Engineering Design Assessment. *Journal of Engineering Education*, 100(4), 778–799. <https://doi.org/10.1002/j.2168-9830.2011.tb00036.x>
- Chien, Y. H., Liu, C. Y., Chan, S. C., & Chang, Y. S. (2023). Engineering design learning for high school and college first-year students in a STEM battlebot design project. *International Journal of STEM Education*, 10(1). <https://doi.org/10.1186/s40594-023-00403-0>
- Crismond, D. P., & Adams, R. S. (2012). The informed design teaching and learning matrix. *Journal of Engineering Education*, 101(4), 738–797. <https://doi.org/10.1002/j.2168-9830.2012.tb01127.x>
- Cross, N. (2000). *Engineering design methods: strategies for product design*. John Wiley & Sons.
- de Haan, G. (2006). The BLK ‘21’ programme in Germany: A ‘Gestaltungskompetenz’-based model for Education for Sustainable Development. *Environmental Education Research*, 12(1), 19–32. <https://doi.org/10.1080/13504620500526362>
- Demetriou, C., Ozer, B. U., & Essau, C. A. (2015). Self-Report Questionnaires. *The Encyclopedia of Clinical Psychology*, 1–6. <https://doi.org/10.1002/9781118625392.wbecp507>
- Edwards, D. B., Sustarsic, M., Chiba, M., McCormick, M., Goo, M., & Perriton, S. (2020). Achieving and monitoring education for sustainable development and global citizenship: A systematic review of the literature. *Sustainability*

- (Switzerland), 12(4), 1–57. <https://doi.org/10.3390/su12041383>
- Ekselsa, R. A., Purwianingsih, W., Anggraeni, S., & Wicaksono, A. G. C. (2023). Developing system thinking skills through project-based learning loaded with education for sustainable development. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, 9(1), 62–73. <https://doi.org/10.22219/jpbi.v9i1.24261>
- Eriksen, M., Lebreton, L. C. M., Carson, H. S., Thiel, M., Moore, C. J., Borerro, J. C., Galgani, F., Ryan, P. G., & Reisser, J. (2014). Plastic Pollution in the World's Oceans: More than 5 Trillion Plastic Pieces Weighing over 250,000 Tons Afloat at Sea. *PLoS ONE*, 9(12), 1–15. <https://doi.org/10.1371/journal.pone.0111913>
- Franco, I. B., Meruane, P. S., & Derbyshire, E. (2020). *Actioning the Global Goals for Local Impact*. https://doi.org/10.1007/978-981-32-9927-6_6
- Franz, R., & Regina, S. (2013). Competences for education for sustainable development in teacher education. *CEPS Journal*, 3(1), 9–24. <https://doi.org/10.25656/01>
- Gill, L. J., Ramsey, P. L., & Leberman, S. I. (2015). A Systems Approach to Developing Emotional Intelligence Using the Self-awareness Engine of Growth Model. *Systemic Practice and Action Research*, 28(6), 575–594. <https://doi.org/10.1007/s11213-015-9345-4>
- Glavič, P. (2022). Updated Principles of Sustainable Engineering. *Processes*, 10(5). <https://doi.org/10.3390/pr10050870>
- Global Education Monitoring Report Team. (2008). Overcoming inequality : why governance matters. In *Book*. UNESCO. <https://doi.org/https://doi.org/10.54676/YIZP6089>
- Haas, B. (2023). Achieving SDG 14 in an equitable and just way. *International Environmental Agreements: Politics, Law and Economics*, 23(2), 199–205. <https://doi.org/10.1007/s10784-023-09603-z>
- Hadjichambis, A. C., & Paraskeva-Hadjichambi, D. (2020). Environmental citizenship questionnaire (ECQ): The development and validation of an evaluation instrument for secondary school students. *Sustainability (Switzerland)*, 12(3). <https://doi.org/10.3390/SU12030821>
- Hake, R. R. (1999). Analyzing Change/Gain Scores. *American Educational Research Association, Division D, Measurement and Research Methodology*, 1–4. <http://www.physics.indiana.edu/~hake>
- Han, H. J., & Shim, K. C. (2019). Development of an engineering design process-based teaching and learning model for scientifically gifted students at the Science Education Institute for the Gifted in South Korea. *Asia-Pacific Science Education*, 5(1), 1–18. <https://doi.org/10.1186/s41029-019-0047-6>
- Harpe, S. E. (2015). How to analyze Likert and other rating scale data. *Currents in*

- Pharmacy Teaching and Learning*, 7(6), 836–850.
<https://doi.org/10.1016/j.cptl.2015.08.001>
- 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>
- Hizqiyah, I. Y. N., Widodo, A., Sriyati, S., & Ahmad, A. (2023). Development of a Digital Problem Solving Skills Test Instrument: Model Rasch Analysis. *Jurnal Penelitian Pendidikan IPA*, 9(4), 1658–1663. <https://doi.org/10.29303/jppipa.v9i4.2671>
- Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark (2006). *Educational Psychologist*, 42(2), 99–107. <https://doi.org/10.1080/00461520701263368>
- Honey, M. A., Pearson, G., & Schweingruber, H. (2014). STEM integration in K-12 education: status, prospects, and an agenda for research. In *STEM Integration in K-12 Education: Status, Prospects, and an Agenda for Research*. <https://doi.org/10.17226/18612>
- Howard, T. J., Culley, S. J., & Dekoninck, E. (2008). Describing the creative design process by the integration of engineering design and cognitive psychology literature. *Design Studies*, 29(2), 160–180. <https://doi.org/10.1016/j.destud.2008.01.001>
- Institut Teknologi Sepuluh Nopember. (2021). *Inovasi Mahasiswa ITS untuk Laut Bebas Mikroplastik*. <https://www.its.ac.id/news/2021/12/03/inovasi-mahasiswa-its-untuk-laut-bebas-mikroplastik/>
- Irnaningtyas, & Sagita, S. (2024). *Buku Paket Biologi SMA/MA Kelas X Kurikulum Merdeka*. Erlangga.
- Jin, S. H., Song, K. Il, Shin, D. H., & Shin, S. (2015). A Performance-Based evaluation rubric for assessing and enhancing engineering design skills in introductory engineering design courses. *International Journal of Engineering Education*, 31(4), 1007–1020.
- Joshi, A., & Pal, D. K. (2015). Likert Scale : Explored and Explained. *British Journal of Applied Science Technology*, 7(4), 396–403. <https://doi.org/10.9734/BJAST/2015/14975>
- Kemdikbud. (2025). *CP & ATP - Biologi Fase E*. Merdeka Mengajar. <https://guru.kemdikbud.go.id/kurikulum/referensi-penerapan/capaian-pembelajaran/sd-sma/biologi/fase-e/>
- Koehn, E. E. (1997). Engineering Perceptions of ABET Accreditation Criteria. *Journal of Professional Issues in Engineering Education and Practice*, 123(2), 66–70.

- Kokotsaki, D., Menzies, V., & Wiggins, A. (2016). Project-based learning: A review of the literature. *Improving Schools*, 19(3), 267–277. <https://doi.org/10.1177/1365480216659733>
- Kopnina, H. (2012). Education for sustainable development (ESD): The turn away from “environment” in environmental education? *Environmental Education Research*, 135–153. <https://doi.org/10.1080/13504622.2012.658028>
- Kopnina, H., & Meijers, F. (2014). Education for sustainable development (ESD): Exploring theoretical and practical challenges. *International Journal of Sustainability in Higher Education*, 15(2), 188–207. <https://doi.org/10.1108/IJSHE-07-2012-0059>
- Küfeoğlu, S. (2022). Emerging Technologies: Value Creation for Sustainable Development. In *Sustainable Development Goals*.
- Labov, J. B., Reid, A. H., & Yamamoto, K. R. (2010). Integrated Biology and Undergraduate Science Education: A New Biology Education for the Twenty-First Century? *The American Society for Cell Biology*, 9, 10–16. <https://doi.org/10.1187/cbe.09-12-0092>
- Lammi, M., & Becker, K. (2013). Engineering Design Thinking. *Journal of Technology Education*, 24(2), 55–77. <https://doi.org/10.21061/jte.v24i2.a.5>
- Landrigan, P. J., Stegeman, J. J., Fleming, L. E., Allemand, D., Anderson, D. M., Backer, L. C., Brucker-Davis, F., Chevalier, N., Corra, L., Czerucka, D., Bottein, M. Y. D., Demeneix, B., Depledge, M., Deheyn, D. D., Dorman, C. J., Fénichel, P., Fisher, S., Gaill, F., Galgani, F., ... Rampal, P. (2020). Human health and ocean pollution. *Annals of Global Health*, 86(1), 1–64. <https://doi.org/10.5334/aogh.2831>
- Law, K. L. (2017). Plastics in the Marine Environment. *Annual Review of Marine Science*, 9, 205–229. <https://doi.org/10.1146/annurev-marine-010816-060409>
- Li, Y., Chen, P., Tang, Y., Yang, Y., Zhou, C., Bu, J., & Zhong, S. (2024). Microplastics in Water: A Review of Characterization and Removal Methods. *Sustainability (Switzerland)*, 16(10). <https://doi.org/10.3390/su16104033>
- Lin, K. Y., Wu, Y. T., Hsu, Y. T., & Williams, P. J. (2021). Effects of infusing the engineering design process into STEM project-based learning to develop preservice technology teachers’ engineering design thinking. *International Journal of STEM Education*, 8(1), 1–15. <https://doi.org/10.1186/s40594-020-00258-9>
- Mergendoller, J. R., & Thomas, J. W. (2000). Managing project based learning: Principles from the field. *Annual Meeting of the American Educational Research Association*, 1–51. <http://www.bie.org/images/uploads/general/f6d0b4a5d9e37c0e0317acb7942d27b0.pdf>
- Mezirow, J. (1997). Transformative Learning: Theory to Practice. In *Newdirections*

- for *Adult and Continuing Education* (pp. 5–12). Jossey-Bass Publishers.
<https://www.ecolas.eu/eng/wp-content/uploads/2015/10/Mezirow-Transformative-Learning.pdf>
- Mogensen, F., & Schnack, K. (2010). The action competence approach and the “new” discourses of education for sustainable development, competence and quality criteria. *Environmental Education Research*, 16(1), 59–74.
<https://doi.org/10.1080/13504620903504032>
- Mogren, A., Gericke, N., & Scherp, H. Å. (2019). Whole school approaches to education for sustainable development: a model that links to school improvement. *Environmental Education Research*, 25(4), 508–531.
<https://doi.org/10.1080/13504622.2018.1455074>
- Molony, B. W., Ford, A. T., Sequeira, A. M. M., Borja, A., Zivian, A. M., Robinson, C., Lønborg, C., Escobar-Briones, E. G., Di Lorenzo, E., Andersen, J. H., Müller, M. N., Devlin, M. J., Failler, P., Villasante, S., Libralato, S., & Fortibuoni, T. (2022). Editorial: Sustainable Development Goal 14 - Life Below Water: Towards a Sustainable Ocean. *Frontiers in Marine Science*, 8(February), 12–15. <https://doi.org/10.3389/fmars.2021.829610>
- Mukti, R. N. (2024). *Pengaruh Pembelajaran Proyek STEM-ESD terkait SDGs Life on Land terhadap Kreativitas dan Aksi Siswa*. Universitas Pendidikan Indonesia.
- Munna, A. S., & Kalam, M. A. (2021). Impact of Active Learning Strategy on the Student Engagement. *GNOSI: An Interdisciplinary Journal of Human Theory and Praxis*, 4(2), 96–114.
<http://gnosijournal.com/index.php/gnosi/article/view/96>
- Murphy, L., B. Eduljee, N., & Croteau, K. (2021). Teacher-Centered Versus Student-Centered Teaching: Preferences and Differences Across Academic Majors. *Joournal of Effective Teaching in Higher Education*, 4(1), 1–22.
<https://jethe.org/index.php/jethe/article/view/156>
- Olino, T. M., & Klein, D. N. (2015). Psychometric Comparison on Self- and Informant-Reports of Personality. *Assessment*, 22(6), 655–664.
<https://doi.org/10.1177/1073191114567942>.Psychometric
- Olsson, D., Gericke, N., & Boeve-de Pauw, J. (2022). The effectiveness of education for sustainable development revisited—a longitudinal study on secondary students’ action competence for sustainability. *Environmental Education Research*, 28(3), 405–429.
<https://doi.org/10.1080/13504622.2022.2033170>
- Pertiwi, T. U., Oetomo, D., & Sugiharto, B. (2024). The effectiveness of STEM Project-Based Learning in improving students’ environmental literacy abilities. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, 10(2), 476–485.
<https://doi.org/10.22219/jpbi.v10i2.33562>

- Quirk, G., & Hanich, Q. (2016). Ocean Diplomacy: The Pacific Island Countries' Campaign to the UN for an Ocean Sustainable Development Goal. *Asia-Pacific Journal of Ocean Law and Policy*, 1(1), 68–95. <https://doi.org/10.1163/24519391-00101005>
- Ragadhita, R., Fiandini, M., Novia, D., Husaeni, A., Bayu, A., & Nandiyanto, D. (2025). Sustainable Development Goals (SDGs) in Engineering Education : Definitions , Research Trends , Bibliometric Insights , and Strategic Approaches. *Indonesian Journal of Science & Technology*, 11(1), 1–26.
- Raja, V., & Fernandes, K. J. (2007). Introduction to Reverse Engineering. In *Reverse engineering: an industrial perspective* (pp. 1–8). Springer Science & Business Media.
- Ribis, E. V. (2024). Fostering Sustainability Through Project-Based Learning: The Sustainable City Project, A Case Study in Primary Education. *Ubiquity Proceedings*, 4(1), 1–8. <https://doi.org/10.5334/uproc.153>
- Rieckmann, M. (2018). Issues and trends in Education for Sustainable Development. In *Learning to transform the world: Key competencies in Education for Sustainable Development* (pp. 39–59). UNESCO. <https://doi.org/10.54675/yelo2332>
- Rokeach, M. (1971). Long-range experimental modification of values, attitudes, and behavior. *American Psychologist*, 26(5), 453–459. <https://doi.org/10.1037/h0031450>
- Sanders, M. (2008). STEM, STEM Education, STEMmania. *The Technology Teacher*, 68(4), 20–26. <http://hdl.handle.net/10919/51616>
- Sarabhai, K. V. (2015). ESD for Sustainable Development Goals (SDGs). *Journal of Education for Sustainable Development*, 9(2), 121–123. <https://doi.org/10.1177/0973408215600601>
- Sass, W., Boeve-de Pauw, J., Olsson, D., Gericke, N., De Maeyer, S., & Van Petegem, P. (2020). Redefining action competence: The case of sustainable development. *Journal of Environmental Education*, 51(4), 292–305. <https://doi.org/10.1080/00958964.2020.1765132>
- Sass, W., Quintelier, A., Boeve-de Pauw, J., De Maeyer, S., Gericke, N., & Van Petegem, P. (2021). Actions for sustainable development through young students' eyes. *Environmental Education Research*, 27(2), 234–253. <https://doi.org/10.1080/13504622.2020.1842331>
- Sauvé, L. (2005). Currents in Environmental Education: Mapping a Complex and Evolving Pedagogical Field. *Canadian Journal of Environmental Education*, 10(1), 11–37. <https://cjee.lakeheadu.ca/article/view/175/9>
- Schmidt, S., Neumann, B., Waweru, Y., Durussel, C., Unger, S., & Visbeck, M. (2017). SDG 14 Conserve and Sustainably Use the Oceans, Seas and Marine Resources for Sustainable Development. In *Identity, Territories, and*

Sustainability: Challenges and Opportunities for Achieving the UN Sustainable Development Goals (pp. 174–218).

- Setyowati, Y., Firda, R., & Kasmita, W. (2021). STEM Education: Exploring Practices Across Education Levels. *Canadian Journal of Science, Mathematics and Technology Education*, 21, 686–690. <https://doi.org/10.1007/s42330-021-00172-4>
- Sholeh, M. I., 'Azah, N., Tasya', D. A., Sokip, Syafi'i, A., Sahri, Rosyidi, H., Arifin, Z., & Ab Rahman, S. F. (2024). Penerapan Pembelajaran Berbasis Proyek (PJBL) dalam Meningkatkan Kemampuan Berpikir Kritis Siswa. *Jurnal Cendekia: Jurnal Pendidikan Matematika*, 6(2), 158–176. <https://doi.org/10.31004/cendekia.v8i2.3361>
- Simarro, C., & Couso, D. (2021). Engineering practices as a framework for STEM education: a proposal based on epistemic nuances. *International Journal of STEM Education*, 8(53), 1–12. <https://doi.org/10.1186/s40594-021-00310-2>
- Sterling, S. (2001). *Sustainable Education: Revisioning Learning and Change* (Issue Vol. 6). Green Books for the Schumacher Society. <https://doi.org/10.4324/9780203875124>
- Sturesson, A., Weitz, N., & Persson, Å. (2018). *SDG 14: Life Below Water*. <https://www.sei.org/wp-content/uploads/2018/11/sdg-14-life-below-water-a-review-of-research-needs-1.pdf>
- Sugiyono. (2018). *Metode Penelitian Kuantitatif, Kualitatif, dan R&D* (Sutopo (ed.); Edisi Kesa). Alfabeta.
- Susilowati, E., Miriam, S., Suyidno, S., Sholahuddin, A., & Winarno, N. (2020). Integration of Learning Science, Technology, Engineering, and Mathematics (STEM) in the Wetland Environment Area to Increase Students' Creativity. *Journal of Physics: Conference Series*, 1491(1). <https://doi.org/10.1088/1742-6596/1491/1/012047>
- Tilbury, D. (2007). Learning based change for sustainability: perspectives and pathways. In *Social learning towards a sustainable world* (pp. 117–131). Wageningen Academic.
- Tilbury, & Daniella. (2011). *Education for Sustainable Development: An expert review of processes and learning* (pp. 1–132). UNESCO.
- UNESCO. (2017). Education for Sustainable Development Goals: learning objectives. In Education for Sustainable Development Goals: learning objectives. In *Education for Sustainable Development Goals: learning objectives*. <https://doi.org/https://doi.org/10.54675/CGBA9153>
- United Nations. (2023). The Sustainable Development Goals Extended Report 2023. In *Statistics Division (UNSD) of the United Nations Department of Economic and Social Affairs*. (Issue April). <https://sdgs.un.org/sites/default/files/2023-07/The-Sustainable-Development->

Goals-Report-2023_0.pdf

- USAID. (2021). *Indonesia Water Resources Profile*. <https://www.globalwaters.org/resources/assets/indonesia-water-resources-profile>
- Vale, I., Barbosa, A., Peixoto, A., & Fernandes, F. (2022). Solving Problems through Engineering Design: An Exploratory Study with Pre-Service Teachers. *Education Sciences*, 12(12). <https://doi.org/10.3390/educsci12120889>
- Widodo, A. (2021). Pembelajaran Ilmu Pengetahuan Alam Dasar-Dasar untuk Praktik. In *UPI Press*.
- Wiek, A., Withycombe, L., & Redman, C. L. (2011). Key competencies in sustainability: A reference framework for academic program development. *Sustainability Science*, 6(2), 203–218. <https://doi.org/10.1007/s11625-011-0132-6>
- Wilhelm, S., Förster, R., & Zimmermann, A. B. (2019). Implementing competence orientation: Towards constructively aligned education for sustainable development in university-level teaching-and-learning. *Sustainability (Switzerland)*, 11(7), 1891. <https://doi.org/10.3390/su11071891>
- Willis, K. A., Serra-Gonçalves, C., Richardson, K., Schuyler, Q. A., Pedersen, H., Anderson, K., Stark, J. S., Vince, J., Hardesty, B. D., Wilcox, C., Nowak, B. F., Lavers, J. L., Semmens, J. M., Greeno, D., MacLeod, C., Frederiksen, N. P. O., & Puskic, P. S. (2022). Cleaner seas: reducing marine pollution. *Reviews in Fish Biology and Fisheries*, 32(1), 145–160. <https://doi.org/10.1007/s11160-021-09674-8>
- WIPO. (2023). Global Innovation Index 2023: Innovation in the face of uncertainty 16th Edition. In *Nucl. Phys.* (Vol. 13, Issue 1).
- Wong, Z. Y., & Liem, G. A. D. (2022). Student Engagement: Current State of the Construct, Conceptual Refinement, and Future Research Directions. *Educational Psychology Review*, 34(1), 107–138. <https://doi.org/10.1007/s10648-021-09628-3>
- Wurdinger, S., Haar, J., Hugg, R., & Bezon, J. (2007). A qualitative study using project-based learning in a mainstream middle school. *Improving Schools*, 10(2), 150–161. <https://doi.org/10.1177/1365480207078048>
- Yuan, J., Ma, J., Sun, Y., Zhou, T., Zhao, Y., & Yu, F. (2020). Microbial degradation and other environmental aspects of microplastics/plastics. *Science of the Total Environment*, 715, 136968. <https://doi.org/10.1016/j.scitotenv.2020.136968>
- Zhao, X., & You, F. (2024). Microplastic Human Dietary Uptake from 1990 to 2018 Grew across 109 Major Developing and Industrialized Countries but Can Be Halved by Plastic Debris Removal. *Environmental Science and Technology*,

58(20), 8709–8723. <https://doi.org/10.1021/acs.est.4c00010>

Ziani, K., Ionit ă-Mîndrican, C.-B., Mititelu, M., Neacsu, S. M., Negrei, C., Morosan, E., Drăgănescu, D., & Preda, O.-T. (2023). Microplastics : A Real Global Threat for Environment and Food Safety : A State of the Art Review. *Nutrients*, 15(3).