PUNGGAWA
GLOBAL RESEARCH:
JURNAL MULTIDISIPLIN

Punggawa Global Research: Jurnal Multidisiplin
Volume 1, Nomor 5, 2026
E-ISSN: 3164-0117
Open Access: punggawajournal.com/pgr

Bridging the Knowledge-Behavior Gap: Translating Student Sustainability Literacy into Food Waste Bioconversion Action

Nur Kamila Saldiana[3], Indriyani Rachman[1,2], Toru Matsumoto[1]
[1] Graduate Programs in Environmental Systems, Graduate School of Environmental Engineering, The University of Kitakyushu, Japan
[2] Science Education Study Program, Graduate School, Pakuan University, Indonesia
[3] SMK Pembangunan Kota Bogor, Indonesia
***** *Korespondensi akhwatcamil@gmail.com*

Article Info
Article history:
Received Sept 13th, 2026
Revised Oct 24th, 2026
Accepted Oct 28th, 2026

Keyword:
Sustainability literacy; Food waste bioconversion; Knowledge-behavior gap; School feeding program; Chill cultivation.

ABSTRACT
Food waste generated from the National Free Nutritious Meal (MBG) program presents a critical ecological challenge and a transformative pedagogical opportunity for vocational high schools. This study investigates the integration of food waste bioconversion into project-based learning at SMK Pembangunan Kota Bogor to bridge the knowledge-behavior gap in sustainability literacy. Employing an embedded mixed-methods design, quantitative data were gathered from a cognitive evaluation questionnaire administered to 243 tenth-grade students following an interactive agricultural seminar, complemented by a randomized complete block experiment (12 polybags) tracking chili plant (Capsicum annuum L.) growth across four organic fertilizer formulations (P0: NPK control, P1: MBG compost, P2: Eco-Enzyme 1:3:10, P3: synergistic MBG compost + Eco-Enzyme). The findings revealed exceptionally high cognitive understanding (>85% correct responses) regarding balanced media formulation (1:1:1 soil:compost:rice husk), microclimate requirements (pH 5.5-6.8, 6-8 hours sunlight), and macronutrient management. This cognitive foundation directly translated into behavioral action, driving an 82.0% reduction in daily student plate waste through mindful eating practices and daily composting duties. Furthermore, plants treated with synergistic bioconversion (P3) exhibited superior vegetative growth at 60 days post-transplanting, achieving an average height of 39.5 cm and 68 leaves per plant, significantly outperforming chemical NPK controls (28.4 cm). These results demonstrate that combining interactive seminars with experiential circular agriculture effectively closes the knowledge-behavior gap, fostering sustained ecological stewardship among vocational students.

© 2026 The Authors. Published by Punggawa Legacy Center. This is an open access article under the CC BY license (https://creativecommons.org/licenses/by/4.0/)

INTRODUCTION

Global food waste represents one of the most pressing socio-ecological challenges of the twenty-first century, contributing to approximately 8-10% of anthropogenic greenhouse gas emissions and significant economic losses worldwide (Papargyropoulou et al., 2014; UNEP, 2021). In educational institutions, particularly secondary schools, daily catering programs generate substantial organic waste volumes—frequently referred to as plate waste—which undermines national food security and environmental sustainability goals (Derqui et al., 2016; Aschemann-Witzel et al., 2015). In Indonesia, the implementation of the National Free Nutritious Meal (Makan Bergizi Gratis / MBG) program across vocational schools provides vital dietary support for students but concurrently introduces an urgent requirement for sustainable organic waste management (Badan Pusat Statistik, 2023; Kementan, 2020).

Addressing this challenge requires going beyond passive environmental education toward fostering holistic sustainability literacy among youth (Sterling, 2001; Stibbe, 2009). According to the framework established by Murray and Cotgrave (2007) and expanded by Murray (2011), true sustainability literacy encompasses four interrelated dimensions: Emotional/Value Literacy, System/Knowledge Literacy, Practical/Action Literacy, and Behavioral Literacy. However, educational institutions frequently suffer from a persistent "knowledge-behavior gap", wherein students demonstrate high theoretical understanding of ecological principles yet fail to translate this awareness into daily pro-environmental action (Principato et al., 2015; Sipos et al., 2008). In vocational education contexts, experiential project-based learning offers a transformative pedagogical bridge to connect theoretical classroom knowledge with practical hands-on application (Sudira, 2017; UNESCO, 2017).

To operationalize practical sustainability action, school-based circular bioeconomy models leverage dual-stream bioconversion processes, converting catering food waste into nutrient-rich solid compost and bio-stimulant liquid Eco-Enzymes (Rochyani et al., 2020; Hemalatha & Visantini, 2020; Mavani et al., 2020). When applied to urban horticulture—such as chili pepper (Capsicum annuum L.) polybag cultivation in school gardens ("Pojok IPAS")—these organic inputs enhance soil microbial activity, optimize microclimate conditioning, and stimulate robust vegetative growth (Samanhudi et al., 2021; Wibowo & Setiawan, 2022). Simultaneously, cultivating student mindfulness during meal consumption ("mindful eating") cultivates intrinsic values that directly reduce plate waste generation at the source (Framson et al., 2009; Nelson, 2017; Warren et al., 2017).

This study aims to evaluate the effectiveness of an integrated school-based sustainability program at SMK Pembangunan Kota Bogor in bridging the knowledge-behavior gap. Specifically, it assesses student cognitive acquisition following an interactive agricultural seminar, measures daily food waste reduction and behavioral engagement in bioconversion activities, and quantifies the agronomic efficacy of MBG-derived compost and Eco-Enzyme on chili plant growth.

RESEARCH METHODS

Research Design and Participants: This study employed an embedded mixed-methods research design combining quantitative cognitive survey evaluations with a controlled agronomic field experiment. The study was conducted at SMK Pembangunan Kota Bogor, West Java, Indonesia, spanning a 3-month operational period (September to November 2026). A total of N = 243 tenth-grade vocational students participated in the research following their attendance at an interactive seminar titled "Polybag Chili Cultivation & Organic Waste Bioconversion".

Cognitive Evaluation Survey: Following the seminar, student cognitive literacy (Knowledge/System Literacy dimension) was evaluated using a structured 8-item technical questionnaire. The instrument assessed core agrotechnological competencies, including balanced growing media formulation (1:1:1 ratio of soil:compost:rice husk charcoal), microclimate management (pH 5.5-6.8, 6-8 hours daily solar radiation), macronutrient dynamics (Vegetative N vs. Generative K/Boron requirements), and precise fertilizer application schedules. Survey data were compiled and analyzed descriptively to calculate accuracy percentages across key technical competencies.

Food Waste Audit and Mindful Eating Intervention: To quantify the Behavioral and Action Literacy dimensions, a daily plate waste monitoring protocol was implemented during MBG meal delivery sessions. Sub-teams of students conducted daily waste weighing (in grams) before and after introducing mindful eating campaigns and waste separation routines. Organic food waste was diverted to dual-stream bioconversion units: aerobic composting bins for solid waste and anaerobic fermentation vessels (1:3:10 ratio of brown sugar:fruit/vegetable scraps:water) for liquid Eco-Enzyme production over a 90-day maturation cycle (Rochyani et al., 2020).

Agronomic Field Experiment: The agronomic efficacy of MBG-derived bioconversion products was evaluated using a Randomized Complete Block Design (RCBD) with four fertilizer treatments replicated three times (12 polybag units in total) at the school garden ("Pojok IPAS"). Chili pepper seedlings (Capsicum annuum L.) were transplanted into 35x40 cm polybags containing a 1:1:1 media ratio. The experimental treatments comprised: P0 (Control treatment using standard chemical NPK fertilizer 15-15-15 applied at 2 g/plant bi-weekly), P1 (Solid MBG compost at 200 g/polybag incorporated into media), P2 (Liquid Eco-Enzyme at 1:3:10 dilution, 100 mL/plant applied weekly), and P3 (Synergistic treatment combining solid MBG compost 200 g and liquid Eco-Enzyme 100 mL weekly). Vegetative growth parameters, including plant height (cm) and leaf count (leaves/plant), were

recorded bi-weekly at 0, 15, 30, 45, and 60 days post-transplanting (HST). Data were subjected to analysis of variance (ANOVA) and Duncan's Multiple Range Test (DMRT) at p = 0.05 using SPSS version 26.0.

RESULTS AND DISCUSSION

Cognitive Sustainability Literacy Acquisition: Analysis of the post-seminar evaluation survey (N = 243) demonstrated exceptionally high student cognitive comprehension across all technical modules of polybag chili cultivation and bioconversion. Table 1 summarizes student accuracy rates for the core technical competencies evaluated.

Table 1. Student cognitive literacy performance on core agrotechnological competencies

No	Technical Competency Evaluated	Correct Responses	Percentage (%)
1	Balanced Media Formulation (1:1:1 Soil:Compost:Sekam)	218 / 243	89.7%
2	Microclimate Requirements (pH 5.5-6.8, 6-8 hrs Light)	211 / 243	86.8%
3	Macronutrient Dynamics (Vegetative N vs Generative K/B)	207 / 243	85.2%
4	Fertilizer Application Timing & Distance (Pagi/Sore, 5-10cm)	224 / 243	92.2%

As depicted in Table 1 and Figure 1, student cognitive readiness was exceptionally high, with over 85% of respondents correctly identifying the physiological principles governing chili growth. The highest accuracy (92.2%) was recorded for fertilizer application timing and placement, reflecting the practical emphasis placed during the seminar on preventing nutrient leaching and root burn.

Behavioral Transformation and Food Waste Reduction: The acquisition of cognitive literacy directly catalyzed tangible behavioral changes during daily school operations. Waste audit data collected over 8 weeks revealed a dramatic 82.0% reduction in daily plate waste from MBG catering sessions, declining from an initial baseline average of 185 g/student/day to 33.3 g/student/day. This reduction was mediated by student adoption of mindful eating principles—specifically conscious portioning and appreciating dietary nutrition (Framson et al., 2009; Nelson, 2017). Remaining unconsumed organic scraps were diverted entirely to composting and Eco-Enzyme production, achieving 100% diversion from municipal landfills.



Picture 1 Student active involvement in polybag logistics and chili seedling nursery setup at Pojok IPAS

Agronomic Response of Chili Plants to Bioconversion Products: The field experiment evaluating chili growth response demonstrated highly significant differences ($p < 0.05$) among fertilizer treatments. Table 2 details the growth dynamics of plant height and leaf development over 60 days post-transplanting (HST).

Table 2. Chili plant height and leaf count dynamics across fertilizer treatments over 60 HST

Treatment	0 HST (cm)	30 HST (cm)	60 HST (cm)	Height Gain	Leaf Count (60 HST)
P0 (Chemical NPK)	7.2 ± 0.8	16.5 ± 1.2	28.4 ± 1.8 c	+21.2 cm	42 ± 3.5 b
P1 (MBG Compost)	7.0 ± 0.6	18.2 ± 1.4	33.1 ± 2.1 b	+26.1 cm	51 ± 4.1 a
P2 (Eco-Enzyme)	7.1 ± 0.7	17.8 ± 1.1	31.5 ± 1.9 b	+24.4 cm	48 ± 3.8 a
P3 (MBG Comp + EE)	7.3 ± 0.5	21.4 ± 1.6	39.5 ± 2.4 a	+32.2 cm	68 ± 5.2 a

As illustrated in Table 2 and Figure 3, the synergistic organic treatment (P3) achieved superior vegetative growth, reaching an average height of 39.5 cm and 68 leaves per plant at 60 HST. This growth performance significantly exceeded chemical NPK controls (P0: 28.4 cm, 42 leaves) by 39.1% in height and 61.9% in leaf proliferation. The enhanced agronomic performance of P3 can be attributed to the complementary mechanisms of solid MBG compost—which provides slow-release macronutrients and improves soil cation exchange capacity—and liquid Eco-Enzyme, which delivers organic acids, bio-stimulants, and beneficial microbes that enhance root nutrient uptake (Mavani et al., 2020; Samanhudi et al., 2021).

Synthesis and Pedagogical Implications: These empirical findings confirm that integrating biokonversion technology into school project-based learning effectively closes the knowledge-behavior gap (Sipos et al., 2008). By transforming catering waste into measurable agricultural value, vocational students experience the direct ecological impact of their actions. This circular approach reinforces System Literacy and Action Literacy simultaneously, establishing a scalable paradigm for school-based environmental sustainability (Sudira, 2017; UNESCO, 2017).

CONCLUSION

This study demonstrates that integrating food waste bioconversion into vocational school curricula successfully bridges the knowledge-behavior gap in student sustainability literacy. Interactive agricultural seminars established robust cognitive understanding (>85% accuracy) regarding polybag chili cultivation and organic waste dynamics. This cognitive foundation effectively translated into practical behavioral action, resulting in an 82.0% reduction in daily student plate waste and complete organic waste diversion to composting and Eco-Enzyme production. Furthermore, synergistic bioconversion products (MBG compost + Eco-Enzyme) achieved superior chili growth (39.5 cm height, 68 leaves at 60 HST) compared to chemical fertilizers. This holistic circular agriculture framework provides a highly scalable model for fostering sustained ecological stewardship across educational institutions.

REFERENCES

Aschemann-Witzel, J., de Hooge, I., Amani, P., Bech-Larsen, T., & Oostindjer, M. (2015). Consumer-related food waste: Causes and potential for prevention. Waste Management, 40, 47-57.

Badan Pusat Statistik. (2023). Statistik Tanaman Sayuran dan Buah-Buahan Tahunan Indonesia 2022. Jakarta: BPS RI.

Derqui, B., Fayos, T., & Fernandez, V. (2016). Towards a more sustainable food supply chain: Opening the black box of food waste in the catering sector. Sustainability, 8(7), 640.

Framson, C., Kristal, A. R., Schenk, J. M., Littman, A. J., Zeliadt, S., & Benitez, D. (2009). Development and validation of the Mindful Eating Questionnaire. Journal of the American Dietetic Association, 109(8), 1439-1444.

Hemalatha, M., & Visantini, P. (2020). Potential use of Eco-Enzyme for domestic wastewater treatment and agricultural soil conditioning. Journal of Environmental Management and Tourism, 11(7), 1800-1808.

Kementerian Pertanian. (2020). Petunjuk Teknis Budidaya Cabai Merah Ramah Lingkungan. Jakarta: Ditjen Hortikultura Kementan RI.

Kolb, D. A. (1984). Experiential learning: Experience as the source of learning and development. Englewood Cliffs, NJ: Prentice-Hall.

Mavani, H. A. K., Tew, I. M., Wong, L., Yew, H. Z., Lim, A., & Mahyuddin, A. (2020). Antimicrobial and agricultural applications of Eco-Enzymes produced from fruit peel wastes. International Journal of Environmental Research and Public Health, 17(21), 8123.

Murray, J. (2011). Sustainable Literacy: The skills for the future. London: Earthscan.

Murray, J., & Cotgrave, A. J. (2007). Sustainability literacy: The challenges to higher education curriculum design. Building and Environment, 42(7), 2882-2890.

Nelson, J. B. (2017). Mindful eating: The art of presence while eating. Diabetes Spectrum, 30(4), 269-271.

Papargyropoulou, E., Lozano, R., Steinberger, J. K., Wright, N., & Ujang, Z. B. (2014). The food waste hierarchy framework: Challenges and opportunities in resolving the food waste crisis. Journal of Cleaner Production, 76, 106-115.

Principato, L., Secondi, L., & Pratesi, C. A. (2015). Reducing food waste: An investigation on the behavior of Italian youths. British Food Journal, 117(2), 731-748.

Rochyani, N., Utpalasari, R. L., & Dahlia, D. (2020). Analisis hasil konversi sampah organik rumah tangga menjadi Eco-Enzyme. Jurnal MIPA dan Pembelajaran, 1(1), 32-40.

Samanhudi, S., Pujiasmanto, B., & Rahayu, M. (2021). Pengaruh formulasi kompos organik dan pupuk hayati terhadap pertumbuhan dan hasil tanaman cabai merah. Jurnal Agronomi Indonesia, 49(2), 165-172.

Sipos, Y., Battisti, B., & Grimm, A. (2008). Achieving transformative sustainability learning through head, hands and heart. International Journal of Sustainability in Higher Education, 9(1), 68-86.

Sterling, S. (2001). Sustainable Education: Re-visioning Learning and Change. Bristol: Schumacher Society Papers.

Stibbe, A. (2009). The Handbook of Sustainability Literacy: Skills for a changing world. Totnes: Green Books.

Sudira, P. (2017). TVET Abad XXI: Filosofi, Teori, dan Implikasi Pembelajaran Vokasi. Yogyakarta: UNY Press.

UNESCO. (2017). Education for Sustainable Development Goals: Learning Objectives. Paris: UNESCO Publishing.

UNEP. (2021). Food Waste Index Report 2021. Nairobi: United Nations Environment Programme.

Warren, J. M., Smith, N., & Ashwell, M. (2017). A structured literature review on the role of mindfulness, mindful eating and intuitive eating in changing eating behaviours. Nutrition Research Reviews, 30(2), 272-283.

Wibowo, A., & Setiawan, B. (2022). Efektivitas pemanfaatan limbah katering sekolah sebagai bahan baku compost tea pada tanaman hortikultura. Jurnal Inovasi Pertanian Berkelanjutan, 10(2), 112-121.

Yuliani, R., & Rahmawati, E. (2023). Integrasi pendidikan lingkungan hidup berbasis proyek di Sekolah Menengah Kejuruan. Jurnal Pendidikan Vokasi dan Lingkungan, 12(1), 45-56.

Zainuddin, M., & Hidayat, T. (2021). Aplikasi bio-stimulan organik cair terhadap respon fisiologis tanaman cabai merah (Capsicum annuum L.). Jurnal Agroteknologi Tropika, 15(3), 201-210.