

STRATEGIC MANAGEMENT OF GREEN COMPETENCY TRANSFORMATION IN VOCATIONAL EDUCATION IN MEDAN CITY: PROJECT-BASED CIRCULAR LEARNING (PBCL) APPROACH

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ABSTRACT

This research aims to analyze the readiness of vocational education institutions in adopting green competencies, develop a *Project-Based Circular Learning* (PBCL) model, and formulate a transformation management strategy to integrate PBCL into the curriculum and culture of the institution. The research uses a *Research and Development* (R&D) approach with a qualitative multiple case study design at vocational education institutions in Medan City. The research is carried out through five stages, namely needs analysis, model design, development and validation, limited implementation, and evaluation. Data is collected through interviews, observations, *Focus Group Discussions* (FGD), and document studies, then analyzed thematically by triangulating sources. The results of the study show that the readiness of institutions in developing green competencies still faces obstacles in terms of leadership, curriculum, lecturer competencies, industrial partnerships, infrastructure, and sustainability culture. The PBCL model developed integrates project-based learning with circular economy principles through multidisciplinary projects that are oriented to real problems. Limited implementation shows that PBCL increases student involvement and develops technical and non-technical competencies related to sustainability. The research also produces a gradual transformation strategy through continuous planning, implementation, and evaluation to support the development of green competency-oriented vocational education.

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INTRODUCTION

The world is currently facing major challenges in the form of an alarming environmental crisis as well as the demands of sustainable economic development. The global development paradigm is beginning to shift from a *linear "take-use-throw-away"* economy to a restorative and regenerative green economy and circular economy. International commitments are reflected in the 2030 Sustainable Development Goals (SDGs) and the Paris Agreement on climate change, which promote economic decarbonization and resource efficiency. As part of the global community, Indonesia has set an ambitious target of (*Measuring Progress Towards an Inclusive Green Economy* , 2012) *Net Zero Emission* (NZE) by 2060 or sooner, as per the *Long-Term Strategy for Low Carbon and Climate Resilience (LTS-LCCR) 2050* (Long-Term Strategy for Low Carbon and Climate Resilience 2050 (LTS-LCCR 2050), 2022) document. This massive transformation towards a green economy is projected to create a new demand for a workforce with green competencies, namely technical and non-technical skills needed to support sustainability in various sectors. (Skills for Green Jobs: A Global View (Synthesis Report), 2011)

The transition to a green economy opens up huge job opportunities in sectors such as renewable energy, waste management, energy efficiency, sustainable agriculture, and others. However, these opportunities are faced with the challenge of a significant skills gap: the available skilled workforce is insufficient in terms of the number and match of skills. As an illustration, Table 1 shows the projected labor needs in several key sectors of the green economy in Indonesia in the coming decade. From the table, it can be seen that the need for *green jobs* reaches hundreds of thousands to millions of people in each sector, especially in sustainable agriculture and renewable energy.

Table 1. Projected Labor Needs

Priority Sectors	Projected Needs (thousand people)	Key Competencies Required
Renewable Energy (Solar, Bioenergy)	950 – 1.200	Solar panel installation, plant operation, energy efficiency analysis
Waste Management & Circular Economy	600 – 850	Eco-friendly product design, recycling management, reverse logistics
Electric & Sustainable Transportation	450 – 600	Electric vehicle maintenance, charging station management, route planning
Sustainable Agriculture & Forestry	1.500 – 2.000	Organic farming practices, product certification, agroforestry management

Source: Adaptation of BAPPENAS & ILO report (2025, hypothetical)

The large number of needs above indicates the need for a very large supply of skilled labor. The strategic position of vocational education as a producer of ready-to-use labor puts it at the forefront of meeting these needs (North Sumatra Central Statistics Agency, 2024). However, the current vocational education system is considered not fully ready to respond to the demands of green transformation, especially in industrial center areas such as Medan City. The city of Medan, as the economic center of North Sumatra, faces an urgent need to have a vocational education system that proactively anticipates changes towards a green industry. Indicators of unpreparedness can be seen from the still high *mismatch* between graduate competencies and industrial needs. The Open Unemployment Rate (TPT) of vocational graduates (e.g. vocational schools) in North Sumatra was recorded relatively high compared to general graduates, indicating a mismatch of skills with new job opportunities, including in the green sector. Medan City employment data also shows an increasing trend of labor force participation, but the absorption of green skilled labor is still not optimal. This situation is a signal that the transformation of curriculum and competencies in vocational institutions needs to be carried out immediately. (North Sumatra Province, 2024)

One of the root problems is that vocational education curricula are still conventional and siloed, so they have not been able to equip students with interdisciplinary and up-to-date green competencies. Existing curricula generally do not integrate sustainability principles comprehensively, limited to elective environmental courses or short modules, without a cross-disciplinary real-practice approach. Shiel and Williams (2023) found that traditional vocational curricula that are boxed per major are less responsive to green economy disruptions (Tarigan et al., 2025) , so

graduates are at risk of falling behind in terms of sustainability skills. Graduates are now not only required to master *technical hard skills*, but also a thorough understanding of product *life-cycle*, resource efficiency, and *soft skills* such as critical thinking, innovation, and collaboration for sustainable solutions. This competency gap underlies the urgency of strategic transformation in vocational education institutions. (Misrah et al., 2024)

This strategic transformation requires innovation in the learning approach. One promising pedagogical approach to answer this need is Project-Based Circular Learning (PBCL). The PBCL model is a synthesis of *Project-Based Learning* (PBL) with circular economy principles. PBL or project-based learning itself is a student-centered learning model, where they develop knowledge and skills through an in-depth investigation process and the completion of authentic projects that are complex and relevant to the real world. Meanwhile, (Daly-Smith et al., 2018) *the circular learning* approach adopts circular economy principles (Reduce, Reuse, Recycle, Remanufacture, Rethink) into the design of the teaching-learning process, encouraging students to come up with solutions that minimize waste and maximize the value of resources. The combination of these two concepts in PBCL allows students not only to learn about sustainability, but also to practice sustainability through real projects. For example, students may be tasked with designing an integrated waste management system on campus, creating products from recycled waste, or developing a business model based on renewable energy. This approach is in line with the need to develop *green skills* that are applicable in the world of work. (Defeyer & German, 2003)

Literature review shows that PBL has various advantages in improving 21st century skills such as collaboration, problem-solving, and critical thinking. Research on the implementation of the circular economy in the industrial world is also growing. However, there is a clear research gap in the intersection of these two concepts in the context of education. There have not been many studies that specifically examine how vocational education institutions can plan, implement, and evaluate the transformation of the curriculum towards green competencies using the pedagogical framework of PBCL. Most previous studies have focused more on the effectiveness of PBL on student learning outcomes, and barely touch on the managerial aspects of the transformation of the institution itself. Aspects such as the role of leadership in curriculum change, lecturer development, resource allocation, partnerships with industry, and efforts to build a sustainable campus culture have not been widely studied in an integrated manner. Moreover, no similar research has been conducted in the city of Medan, which has its own characteristics and local potential in the green economy transition. (Hargreaves & Fullan, 2020) (Geissdoerfer et al., 2017)

Based on the above explanation, this research was conducted to fill the knowledge gap by developing a strategic management model for the transformation of the vocational curriculum towards PBCL-based green competencies. In particular, this study answers four main questions: (1) how the readiness conditions and challenges of vocational education institutions in Medan City in adopting the current green competency-based curriculum; (2) how the *PBCL pedagogical model* can be designed effectively to develop students' green competencies; (3) how the *transformation management strategy* (planning, implementation, evaluation) is most effective to integrate PBCL into the curriculum system and institutional culture; and (4) what are the *implications of implementing this transformation strategy* on stakeholders. The research is expected to produce a managerial and pedagogical model that can serve as a practical reference for other vocational education institutions in similar efforts, as well as contribute to the literature on educational strategies towards a green economy.

METHOD

This research uses a Research and Development (R&D) approach with a qualitative multiple case study design. The R&D design was chosen so that the researcher can develop the model systematically while conducting limited trials to obtain empirical feedback. The research subject is a vocational education institution at the Polytechnic level in Medan City, focusing on several study programs relevant to the green industry sector (for example, Automotive/Mechanical Engineering for the electric transportation and circular manufacturing sectors, as well as Tourism study programs for the sustainable tourism sector). The research was conducted in the period of August-October 2025 at the Medan State Polytechnic as the main case study, by also involving partner Polytechnics in Medan and several green industrial companies as partners for field study sites. (Rachman et al., 2024; Sugiyono, 2017)

This R&D research stage includes five main iterative phases: (1) Needs Analysis, (2) Model Design, (3) Development and Validation, (4) Limited Implementation (Pilot Project), and (5) Evaluation. In the Analysis stage, the researcher identifies the initial conditions, needs, and challenges in the transformation of green competencies at the target institution. Qualitative data collection techniques used in this stage include in-depth interviews with key informants, including institutional leaders (directors/deputy directors), study program chairs, lecturers. The selection of informants is carried out purposively based on the relevance of their roles. The interview aims to explore perceptions, experiences, and expectations related to the implementation of the green curriculum and PBCL from various stakeholder perspectives. Limited participatory observation was carried out in the campus environment to observe the condition of supporting facilities (e.g. the availability of green laboratories, waste management practices on campus) and observe the learning process that is currently running as *a baseline*. Focus Group Discussion (FGD) with lecturer groups and student groups separately. FGD was used to trigger a collective discussion on PBCL design ideas, challenges faced in the field, and input on implementation scenarios. Document studies were carried out by analyzing institutional documents such as curriculum and study program syllabus, polytechnic strategic plans, study program development roadmaps, and reports on industry needs related to green competencies (e.g. industry association reports, government regulations related to *green jobs*).

Qualitative data collected through the various techniques above is then analyzed using thematic analysis techniques. The researcher transcribes interviews and FGDs, then codes to group information into themes according to the dimensions studied (for example, findings related to leadership, curriculum, human resources, and so on). Triangulation of sources is carried out by comparing information from various stakeholder interviews, observations, and documents to ensure the consistency of findings (credibility). The involvement of *peer debriefing* with other members of the research team and confirmation to informants (member checking) is carried out to increase the validity of the analysis results.

Based on the findings of the analysis stage, at the Design stage, an initial framework for the transformation strategic management model and learning design of PBCL was developed. This initial model includes: the vision and objectives of the transformation, the key components of the PBCL model (e.g. project structure, circular teaching materials, collaboration mechanisms with industry), and gradual implementation plans in the institution. The limited implementation phase is carried out in the form of a pilot project for the implementation of PBCL in the Polytechnic environment. The pilot project is carried out on a small scale, for example in one class or one course module in the current semester, involving lecturers and students who have been prepared. For example, a circular economy-based project is implemented for several weeks: automotive engineering students are asked to design a prototype for the management of oil waste and motor vehicle batteries, guided by lecturers and experts from the industry. During the pilot, the researcher observed and measured the practicality of the model: how students responded, difficulties that arose, and the readiness of lecturers in facilitating PBCL. The final stage, Evaluation, was conducted to assess the initial effectiveness and prepare recommendations for improvement. The evaluation included the analysis of feedback from lecturers and students participating in the pilot (through questionnaires or reflective interviews) as well as the achievement of project outputs. In addition, the researcher compared *the conditions before and after* the pilot in terms of indicators of the learning process (e.g. student involvement, skills that emerged) although no in-depth quantitative measurement of learning outcomes was carried out in this study. The results of the evaluation were used to modify the final model. The entire process of this research adheres to research ethics; The participation of the informant is voluntary by first giving written consent, and the confidentiality of the respondent's information is maintained.

With the above method, the research not only produces diagnostic *insights* regarding institutional readiness, but also a solution prototype (PBCL model) that has been tested practically in a limited scope. This gives strength to the research, as the resulting model has gone through initial empirical verification before being proposed for wider adoption.

RESULT AND DISCUSSIONS

Producing a distributed field of visibility

The results of the needs analysis show that the level of readiness of vocational education institutions in Medan City in adopting a green competency-based curriculum is still relatively low, with various challenges in each strategic dimension. First, from the leadership aspect, it is found that the vision and commitment of the leadership to "green" initiatives still needs to be strengthened. Although the leadership of the Polytechnic generally supports the idea of sustainability, there is no written policy or strategic plan of the institution that explicitly makes green skills a priority. The involvement of leaders in programs related to the environment is sporadic, for example, only supporting *ad hoc events* such as tree planting days, and has not reached the stage of leading systematic curriculum changes. The lack of sense of urgency at the leadership level is the initial challenge in driving transformation (Kotter, 1996).

Second, the current curriculum aspect is still lagging behind in integrating circular economy and sustainability materials. The curriculum structure in the surveyed study programs generally does not include special courses related to green economy or environmentally friendly technology. For example, in engineering programs, the topic of renewable energy or waste management is only inserted a little in general courses, even if it is limited to theory. The syllabus of most study programs is still oriented towards *conventional technical competencies* according to the old industry. This is in line with the finding that vocational curricula tend to be *Shirley (2016) be silophilic* (compartmentalized) and less able to meet the needs of interdisciplinary skills such as green competencies. Curriculum challenges include the need to restructure *learning outcomes* that incorporate sustainability principles, the development of new teaching materials, and flexibility so that students can work on cross-course projects.

Third, lecturers' human resources are still in the early stages of readiness. Most lecturers do not have specific knowledge and skills in the field of green economy or innovative pedagogy such as circular-based PBL. From the interviews, lecturers admitted that there is still limited training they take in related to green skills. Some senior lecturers tend to be comfortable with traditional lecture methods and are less familiar with project-based learning. The readiness of these lecturers is very crucial because they are at the forefront of the implementation of PBCL in the classroom. Efforts to improve lecturers' competence are needed through (Hargreaves & O'Connor, 2017) *training of trainers*, circular economy workshops, and assistance in designing PBCL projects.

Fourth, industrial partnerships related to the green economy have not been optimally utilized. Polytechnics in Medan actually have a network of cooperation with various companies, but partnerships that specifically support the green curriculum are still rare. Green industries (such as waste management companies, renewable energy) have not been widely involved in curriculum formulation or the provision of real projects to students. As a result, vocational students are less exposed to the latest green industry best practices. The results of FGDs with industry representatives show that their readiness to get involved actually exists, for example through green thematic internship programs, as long as institutions proactively establish collaboration. The challenge here is to design a mutually beneficial partnership scheme, where the industry can be a source of learning cases/projects and at the same time a potential user of graduates with green competencies. (Osmond-Johnson & Fuhrmann, 2022)

Fifth, in terms of infrastructure, institutions face limited facilities to support green practices. Most laboratories and practical equipment still focus on old technology. For example, campus automotive workshops are not equipped with electric vehicle equipment or renewable energy simulations. Likewise, waste management facilities (waste banks, recycling tools) are almost non-existent. Digital infrastructure for simulations is also limited. Without adequate infrastructure, the implementation of green projects will be less than optimal. This challenge requires investment and reorientation of the institution's budget. One of the interesting findings is that several lecturers and students have taken small initiatives such as creating mini hydroponic gardens and compost bins in the corner of the campus independently. This shows that there is bottom-up potential that can be supported if the institution provides better facilities. (Melesse & Belay, 2022)

Sixth, institutional culture related to sustainability is still in the formation stage. There is no *strong green campus culture* at the Polytechnic. For example, there has been no implementation of integrated waste sorting policies on campus, the reuse of used materials, or energy-saving traditions. Campus residents' participation in environmental

care activities is relatively low except for ceremonial events. For successful transformation, an institutional culture that supports sustainability values needs to be instilled. This includes changing the mindset of students and staff to be more environmentally friendly, as well as incentives or internal rules that encourage environmentally friendly practices.

Overall, it can be concluded that vocational education institutions in Medan are not fully prepared in terms of leadership, curriculum, human resources, partnerships, infrastructure, and culture to carry out the transformation towards green competence. These challenges are certainly obstacles, but on the other hand they are the focal point of intervention in strategy design. This mapped baseline condition provides a foothold for research to design a transformation model that is right on target, adjusting to real gaps and needs. These findings are also consistent with the ILO (2011) and UNEP (2012) reports that the transition to a green economy needs to be supported by education and training system reforms, because without it there will be a shortage of skilled workers even though green job opportunities are wide open.

Desain Model Pedagogis Project-Based Circular Learning (PBCL)

Answering the second question, this research resulted in the design of a contextual PBCL pedagogical model to develop the green competencies of vocational students. The PBCL model was designed by referring to the *principles of student-centered learning* from PBL and the integration of sustainability values from the circular economy. The design results include the structure, content, and mechanism of implementing PBCL in the classroom that has been adjusted to the conditions of the Polytechnic. Structurally, the PBCL model developed organizes the learning process in the form of multidisciplinary projects that last for one period/semester. Each PBCL project starts from a *challenge statement* related to real sustainability problems in the local or industrial environment. For example, a project for mechanical engineering students: "Designing an innovative tool that can recycle plastic waste into raw materials for 3D printing". The project then guides (Ball & Christensen, 2019) *the learning units* across several courses, so that students can apply knowledge from different disciplines (mechanics, materials, environment) to solve these challenges. This approach ensures that the required green competencies (such as eco-design, *problem solving*, collaboration) are honed integratively, rather than fragmented.

In terms of content, the project curriculum is structured based on the 5R (Reduce, Reuse, Recycle, Remanufacture, Rethink) principles of the circular economy. This means that each PBCL project must contain elements that encourage students to think about waste reduction, material reuse, process recycling, product reengineering, and business model rethinking. The technical content is tailored to the major; for example, for the tourism Gastronomy program, the project can be in the form of "Creating (Askiyanto et al., 2024) *a zero-waste restaurant menu*" that focuses on food waste management and raw material efficiency. In addition to technical content, the PBCL module also integrates the development of *sustainability soft skills*, such as *life cycle analysis*, environmental ethics, persuasive communication for green campaigns, etc. Thus, a *hidden curriculum* regarding sustainable values is also contained.

The implementation of the PBCL model involves special facilitation and evaluation methods. Lecturers play the role of project facilitators and *coaches* rather than just theoretical teachers. To support lecturers, a PBCL implementation guide was designed which contains steps: starting from how to prepare a project scenario, forming a cross-skill student group, scheduling project milestones, to techniques to guide students to reflect on sustainability. The results of the study recommend team *teaching*, where several lecturers from different courses collaborate to guide one large project. This is to ensure the integration of knowledge and facilitate cross-course assessment. In the PBCL model, collaboration with industry and communities is a key component. Student projects are sought to involve external *stakeholders*: for example, recycling projects in collaboration with local recycled MSMEs, or renewable energy projects in partnership with local PLN. The involvement of these partners provides context and real data for students, as well as strengthens *experiential learning* aspects. This research designs an industry participation scheme, for example through *guest lectures* at the beginning of the project, providing case studies, remote mentorship, and becoming judges at the final presentation of project results. That way, students feel the standards and expectations of the green industry world from the learning process.

The expected output of this PBCL model is not only conceptual knowledge, but also real products or prototypes of green solutions. The evaluation of learning focuses on the quality of the final project and the process undertaken by the student team. The assessment uses a performance rubric that includes technical indicators (the function and innovation of the product/solution made), sustainability indicators (how much potential waste reduction/efficiency their ideas produce), and generic skills indicators (teamwork, creativity, problem-solving). This rubric is compiled with reference to the PBL literature but adds a green skills dimension according to the UNEP (2012) framework. (Siagian et al., 2025; Yanti & Marsudi, 2025)

Transformation Management Strategy for PBCL Integration

The third aspect of the research formulates an effective transformation management strategy so that the PBCL model can be integrated sustainably into the curriculum system and culture of vocational institutions. This strategy includes the stages of planning, implementation, and evaluation of change, in line with organizational change management theory. (Al Zuhurf et al., 2026)

At the strategic planning stage, the first thing that is suggested is to build a *sense of urgency* among leaders and academics regarding the need for green competency transformation. The findings of the study show that without the encouragement of vision from leaders, change initiatives tend to stall. Therefore, it is recommended that institutional leaders establish formal policies, such as the Director's Decree, which states a commitment to integrate circular economy principles into education. Leaders need to form a steering committee for the transformation of the green curriculum consisting of structural officials (deputy academic directors, department heads) and champion lecturers who have an interest in learning innovation. This team is tasked with formulating a master plan for the implementation of PBCL, including short-term and long-term targets. For example, the first year target: PBCL pilots in 2 study programs; The third year target: all study programs implement at least one PBCL project every year. Planning also includes *resource assessments: budget allocation for lecturer training and the procurement of props, as well as implementation scheduling synchronized with the academic calendar*.

An important step in planning is socialization and internal stakeholder involvement from the beginning. An effective change strategy emphasizes vision communication. In this context, management should hold workshops or group forums to present the findings of the analysis (e.g. green competency gap data) to lecturers and staff, so that understanding and support emerge. Lecturers need to be convinced that this transformation is not just an additional burden, but an opportunity to improve the quality of learning and relevance of graduates. Involving key lecturers in planning (e.g. co-developing a new curriculum) will foster a sense of ownership of change, which is crucial to overcome potential resistance. (Seccatore et al., 2014)

The implementation phase of the transformation strategy focuses on gradual implementation and intensive mentoring. The research recommends a *pilot and scale-up approach*, which is to start the implementation of PBCL on a small scale (pilot projects in several classes) before expanding to all institutions. This strategy is in line with the concept of *quick wins* (Kotter, 1996) where the success of the early stages is used as a showcase to encourage wider support. In the implementation of the pilot, the steering team must provide a strong support system: *capacity building programs* for lecturers (PBCL methodology training, project preparation workshops), providing modules and learning tools that have been prepared by researchers, as well as supporting facilities (e.g. group workspaces, consumables for projects). During implementation, regular monitoring is carried out. The person in charge of PBCL at the department level should hold weekly meetings with the implementing lecturer to monitor the progress of student projects, solve obstacles that arise, and share good practices. This horizontal communication pattern such as a community of practice is effective in maintaining the momentum of change. (Kotter, 2012)

In addition, cultural change management is also applied at the implementation stage. For example, institutions can hold a *Green Innovation Expo event* at the end of the semester where the results of students' PBCL projects are exhibited. This activity not only gives appreciation to students and lecturers, but also invites external stakeholders (industry, local governments) so as to build a new image of the campus as a pioneer of green vocational. Gradually, the institution will develop a culture that values innovation and sustainability. Also, internal rules can be changed to support the new culture: for example, including the criteria of "green learning initiatives" in the award scheme for

outstanding lecturers, or implementing an environmentally friendly campus policy (reduction of single-use plastics, energy efficiency) so that the campus environment is aligned with the content of PBCL.

In the aspect of integrating into the system, it is necessary to ensure that the output of PBCL enters the formal mechanism of the institution. This means that the results of the evaluation and experience from the PBCL pilot must be used to revise the official curriculum. The curriculum team in the study program needs to adopt the PBCL module as part of the curriculum (not extra-curricular activities). For example, adding the "Circular Economy Applied Project" course with a weight of 3 credits that must be followed by final year students across study programs, as an institutional forum of PBCL. Thus, PBCL becomes permanent in the academic structure, not just a temporary trial.

The last stage is continuous evaluation and feedback. The transformation strategy emphasizes the importance of formative evaluation in each phase. The steering team periodically evaluates the achievements: whether the implementation targets are achieved, what obstacles, how students and lecturers respond. The evaluation instruments used in the research (interviews/reflective FGDs, project assessment rubrics) can be continuously utilized. The results of the evaluation are then formulated into further policies. For example, if it is found that lecturers are overwhelmed to guide the project because the student ratio is too large, the institution can respond by reducing the number of students per class or adding assistants. The evaluation should also include long-term output aspects: for example, tracking alumni who participate in PBCL, whether it is easier to be absorbed in the green industry. Although this research does not reach that stage, in the future the institution can work with graduate users to obtain data on the impact of this transformation. (Osmond-Johnson & Fuhrmann, 2022)

By implementing the above change management strategies, the integration of PBCL into the curriculum and institutional culture is expected to be effective and sustainable. The key to success is visionary and consistent leadership, active involvement of lecturers and stakeholders, adequate provision of resources, and adaptive evaluation mechanisms. This approach is in line with the principle of strategic management of education that curriculum changes must be supported by holistic organizational change. This means that it is not enough to just replace teaching materials, but it is necessary to change the supporting system including human resources, structure, and culture. The strategy of this research offers a model that can be replicated in other vocational institutions, of course, by adjusting their respective contexts. (Hák et al., 2016)

Implications of Implementing Transformation Strategies for Stakeholders

The implementation of PBCL-based green competency transformation strategies in vocational institutions has wide implications for various stakeholders, both internal and external. For students, the implementation of PBCL directly improves the quality of learning and their work readiness. Students get learning experiences that are more relevant to the real world, direct involvement in solving sustainability problems makes them master *applied hard skills* (for example, operating environmentally friendly technology) as well as *soft skills* such as cross-disciplinary collaboration. The positive implication is that Polytechnic graduates who go through this green curriculum will have higher competitiveness in the job market, especially in green sectors that are developing. They not only have vocational diplomas, but also a portfolio of green innovation projects that can be shown to potential employers. This is in line with the government's goal of reducing labor *mismatch*; graduates with green skills are expected to be more absorbed so as to reduce educated unemployment. On the other hand, the challenge for students is that they are required to adapt to a more independent and intense learning method. Not all students are familiar with PBL, so they need guidance at first. However, based on the pilot's response, the majority of students enthusiastically welcomed this PBCL method because they felt more challenged and not bored than conventional lectures. (North Sumatra Province, 2024)

For lecturers and educators, this transformation requires increasing professional competence as well as changing roles. Lecturers need to learn a lot of new things: both technical content related to green technology and project-based teaching skills. The practical implication is that institutions must facilitate lecturer training and *upskilling programs* on an ongoing basis. In terms of workload, in the early stages of implementing PBCL, lecturers' workload tends to increase because they have to prepare complex projects and coordinate across courses. This can cause resistance or fatigue if it is not balanced with support. Therefore, management needs to recognize the contribution of lecturers in the implementation of PBCL, for example by providing incentives, special performance

loads, or making these activities part of performance assessments. In the long run, the implications are positive: lecturers will develop innovative pedagogical skills and conduct *action research* from PBCL practices, which can enhance their academic careers (publications, innovative educator certifications, etc.). Lecturers will also be better connected to the industry through project mentorship, expanding professional networks. (Al Zuhurf et al., 2026)

For institutional management (leadership), the success of transformation will have an effect on the reputation and performance of the institution. Polytechnics that successfully integrate green competencies will be known as pioneers of sustainable vocational education, which can increase the attractiveness of prospective new students and the trust of industry partners. However, the implication is that leaders must be ready to carry out institutional reforms that may not always be easy. For example, it is necessary to adjust the official curriculum (must coordinate with the Directorate General of Vocational Education or BAN-PT for curriculum changes), allocate a special budget (perhaps at the expense of other budget posts), and change some academic rules. Leaders must also be prepared to face risks if there is failure or criticism in the early stages, such as student projects that are not successful, or there are complaints from parents who do not understand the PBL method. All of this needs to be mitigated by careful change management. In general, the implication for institutions is the need for consistent policy support and funding. Polytechnics can include the "Green Campus" agenda in their medium-term strategic plans to ensure their sustainability, and seek external funding sources (grants, industry CSR) to help finance these programs.

For industry partners and the business world, involvement in green vocational education provides long-term benefits in the form of the availability of human resources that meet their needs. Industries that collaborate with campuses through PBCL will gain early access to talents trained in real projects. Implication, this model can strengthen the *link and match* between vocational and industry. However, the industry needs to invest time and resources (e.g. staff being guest supervisors, accepting interns for projects). For some small companies, this may be a burden, but it can be overcome by explaining the long-term benefits and perhaps incentives (recognition as a partner, direct recruitment opportunities). Local governments can also be involved, for example the Manpower Office or the Education Office can facilitate this collaboration within the framework of regional vocational programs. On a macro level, industrial involvement and the absorption of green graduates will help accelerate the government's green economy agenda.

For the government and education policymakers, the findings and models of this study provide important implications as a consideration for the development of the national curriculum. If this model proves to be effective, it is not impossible that it can be replicated to other vocational schools or polytechnics in Indonesia. The government can make PBCL one of the leading learning models in the future-oriented vocational curriculum guidelines. Of course, standardization and adjustment are needed, but the essence of integrating circular economy principles into vocational education is in line with the direction of national policies in the development of competitive and environmentally sound human resources. Another implication is that this green vocational transformation program can support the achievement of Indonesia's targets on the global agenda (climate NDCs, quality education SDGs, and climate action). Thus, at the policy level, the results of this study provide empirical justification that investment in "greening TVET" (Technical and Vocational Education and Training) is very necessary and beneficial.

Finally, for the wider community and the environment, although the impact is not instantaneous, the implementation of green vocational education has long-term strategic implications. Skilled and environmentally conscious vocational graduates will become agents of change in their respective workplaces and communities. They can implement environmentally friendly practices in the industry, encourage green innovation, and increase public awareness. On a micro scale, student projects during PBCL can directly benefit the community, for example waste treatment prototypes carried out by students can be implemented in the environment around the campus. This creates a positive domino effect towards sustainable development. The community will feel the concrete role of educational institutions in solving local problems (such as waste, energy) through student innovation. Thus, there is a strengthening of the relationship between the vocational campus and the community, where the campus contributes as a *problem solver* to local sustainability issues.

Overall, the implications of implementing this PBCL-based green competency transformation strategy are very broad. To maximize positive impacts and minimize negative impacts, it is important for each stakeholder to adapt to their new roles. Collaboration between parties (campuses, lecturers, students, industry, government) is key in this innovation ecosystem. This research has succeeded in identifying potential benefits and obstacles for each stakeholder, which can then be used as a reference in developing a comprehensive implementation plan. With a shared commitment, this transformation is expected to run smoothly and the ultimate goal – which is to produce green competent vocational graduates who are ready to build a green economy – can be realized.

CONCLUSION

This study concludes that the transformation of vocational education towards a green competency orientation requires planned changes in the aspects of curriculum, learning, human resources, partnerships, infrastructure, and institutional culture. A case study on polytechnics in Medan City shows that the readiness of institutions in adopting a green curriculum still faces various obstacles, especially the limited integration of sustainability materials in the curriculum, lecturers' competence in green pedagogy and technology, partnerships with green industries, and facilities that support circular economy practices. Nevertheless, the initial awareness of the academic community and policy support for the green economy are important capital for institutions to carry out transformation.

In response to these conditions, this research produced a *Project-Based Circular Learning* (PBCL) model that integrates *project-based learning*, circular economy principles, and the development of *green skills* in vocational learning. Through real, cross-disciplinary projects involving students, lecturers, and industry partners, PBCL is able to increase learning engagement and develop technical and non-technical competencies related to sustainability. Its implementation is supported by an institutional transformation strategy that includes three stages, namely planning through the establishment of a green vision and the formation of a driving team, gradual implementation through *pilot projects*, strengthening the capacity of lecturers and support systems, and continuous evaluation as the basis for refinement and expansion of model implementation.

Overall, PBCL provides a conceptual framework as well as a practical guide for vocational institutions in developing education that is responsive to the needs of the green economy. This transformation has implications for increasing student competence and competitiveness, professional development of lecturers, strengthening institutional capacity, and expanding collaboration with industry and government. However, this research is still limited to the scope of the trial and has not measured the long-term impact on graduate competence and labor absorption in green industries. Further research is needed to evaluate these impacts and test the application of PBCL in different institutions, regions, and vocational education levels.

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