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Strengthening High School Students' Soft Skills through a Co-curricular Physics Program Integrated with Motorcycle Engineering and Business Competencies

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A B S T R A C T

The strengthening of science concepts in the Merdeka Curriculum requires a strong linkage between theoretical understanding and authentic application, particularly to develop soft skills relevant to the 21st-century workforce. However, physics learning in senior high schools still tends to emphasize cognitive aspects and provides limited practical exposure. This study aims to bridge this gap by integrating physics learning with competencies from the Motorcycle Engineering and Business (TBSM) program through a project-based co-curricular activity titled "Energy Efficiency and Workshop Service Innovation" at SMAN 2 Sandai. Employing a descriptive-qualitative method, data were collected through observation, semi-structured interviews, document analysis, triangulation, and member checking. The findings indicate differentiated soft-skill development among 26 participating students: three students reached Level 4, showing strong diagnostic abilities, data-based reasoning, scientific communication, and leadership; students at Level 3 demonstrated adequate mastery of concepts but inconsistencies in decision-making; while those at Levels 2–1 required further improvement in work discipline and entrepreneurial orientation. Overall, the study concludes that contextual project-based experiences effectively strengthen the connection between physics concepts and technical competencies while fostering students' professional character development.

1. Introduction

The transformation of education in the era of the Industrial Revolution 4.0 demands a shift in learning paradigms from merely emphasizing cognitive achievements toward developing more comprehensive competencies. These competencies encompass not only hard skills but also soft skills, which are essential for preparing younger generations to face global challenges. At the senior high school level, this shift is crucial to be realized through contextual learning approaches that align with the dynamics of the industrial world and future demands. Physics learning, as part of science education, holds significant potential to integrate cognitive and social aspects because it requires critical thinking, problem solving, scientific communication, and collaboration skills (Ardiyanti & Nuroso, 2021; Jayadi et al., 2020). However, the reality in the field shows that physics instruction often remains focused on academic achievement alone and has not optimally supported the development of students' social character (Riadi & Nugroho, 2020).

A growing body of research demonstrates that integrating soft skills into science learning provides substantial positive impacts. Such integration can foster student character and responsibility, increase active learning engagement (Hermawan et al., 2023), and promote creativity and collaborative abilities (Maysyaroh & Dwikoranto, 2021; Saldo & Walag, 2020). One increasingly relevant approach is the utilization of co-curricular activities as a bridge between academic knowledge and real-world practice (Rahayu et al., 2021). In vocational education, the relevance of physics to motorcycle engineering and business fields offers a strategic opportunity to develop more applicable and meaningful learning. Physics concepts such as energy, torque, efficiency, friction, and motion dynamics are directly applicable to the operational mechanisms of motor vehicles as well as to managerial aspects of business (Nurtang, 2019). Such interdisciplinary approaches not only strengthen scientific understanding but also enrich students' soft skill competencies (Chioda et al., 2021; Facca et al., 2020).

The implementation of this integration can be carried out through contextual project-based activities. These may include analyzing motorcycle engine performance, designing simple tools to improve energy efficiency, or developing innovations based on mechanical principles (Umamah & Andi, 2019). These activities have been shown to enhance students' communication, collaboration, and leadership skills through teamwork, discussions, and project presentations (Cutri et al., 2023). Moreover, such co-curricular programs also help cultivate positive character traits such as discipline, work ethic, and entrepreneurial mindset (Rumerung et al., 2023a). In the context of 21st-century competencies, strengthening students' critical thinking, creativity, communication, and collaboration is becoming increasingly important (Haqiqi et al., 2020; Sanjayanti & Pramadi, 2020; Sumiati et al., 2018). The integration of physics with automotive practice has also been proven to enhance higher-order thinking skills and scientific communication through authentic learning experiences (Dziob et al., 2022). Despite these various benefits, many schools still lack structured co-curricular designs that explicitly aim to strengthen students' soft skills. The absence of clear guidelines and program models often results in less optimal implementation of co-curricular activities. Therefore, it is necessary to develop a structured, contextual, and evidence-based co-curricular physics program integrated with motorcycle engineering and business practices that meets students' real needs. Based on this urgency, the purpose of this study is to design and analyze a physics co-curricular program integrated with motorcycle engineering and business as a strategy to strengthen soft skills among senior high school students.

2. Methodology

This study employed a descriptive–qualitative approach supported by simple quantitative data to comprehensively examine how a physics co-curricular program integrated with the Motorcycle Engineering and Business (TBSM) competencies can strengthen high school students' soft skills (Creswell, 2015). The integration of qualitative and quantitative elements was used to provide a richer understanding of the learning process, the dynamics of student participation, and the observable development of soft skills throughout the program. The co-curricular activities were implemented at SMAN 2 Sandai over the course of one semester (July–December 2025), involving 26 twelfth-grade students selected through purposive sampling based on their motivation, availability, and relevance to the program's objectives. The targeted soft skills included communication, collaboration, critical thinking, and work responsibility competencies widely recognized as essential in the 21st-century learning framework and aligned with the demands of industrial-vocational contexts.

Data collection employed multiple techniques to capture both the process and outcomes of the co-curricular implementation. Participatory observation allowed the researchers to directly monitor student interactions, engagement, and problem-solving behaviors during project activities. Semi-structured interviews were conducted with students and teachers to explore their perceptions, experiences, and reflections regarding the physics–TBSM integration. Document analysis was carried out on students' project reports, performance artifacts, attendance records, and teachers' instructional notes. Instruments used in the study included structured observation sheets, interview guides, documentation protocols, and validated learning goal achievement rubrics, which were strengthened through expert judgment to ensure alignment with competency indicators.

To establish the credibility and dependability of the findings, data validity was ensured through triangulation of techniques (observation, interview, documentation) and sources (students, teachers, and program artifacts). Member checking was carried out to confirm the accuracy of interview interpretations, while inter-rater reliability was established by involving two independent coders to evaluate soft skill development indicators. The data analysis followed an interactive model consisting of iterative cycles of data reduction, data display, and conclusion drawing. Data reduction involved selecting, simplifying, and coding relevant information; data display included organizing patterns and themes in descriptive matrices; and conclusion drawing was performed by interpreting the emerging findings and verifying them through continuous comparison with field data.

3. Results and Discussion

Physics learning in the *Merdeka Curriculum* not only emphasizes mastery of concepts but also the development of soft skills as a foundation for work readiness, particularly in vocational fields such as Motorcycle Engineering and Business (TBSM). The integration of physics with workshop practice enables students to apply concepts of force, energy, torque, and efficiency in the process of engine diagnostics and servicing, while simultaneously fostering critical thinking, problem-solving, collaboration, and communication skills (Ayudha & Setyarsih, 2021). Effective science learning should cultivate both character and soft skills (Daniah, 2017), who emphasize that 21st-century competencies demand creativity, cooperation, and leadership. In the vocational context, the relationship between technical hard skills and soft skills is the key to successful workshop services and industry readiness. Therefore, mapping competencies that synergize Physics Learning Outcomes (CP Fisika), soft skills, and TBSM competencies is essential to produce contextual, meaningful, and relevant learning experiences, as shown in the following Table 1.

Table 1. Needs Analysis

Component	Primary Needs	Indicators	Activities
Physics Learning Outcomes	Mastery of concepts of force, energy, power, electricity, and waves	Ability to analyze physical phenomena in technological contexts	Experiments on force and motion; analysis of engine power; ignition system simulation
Soft Skills	Critical thinking, problem-solving, communication, collaboration	Work readiness and 21st-century skills (4C)	Damage diagnosis discussions; presentation of engine performance test results
TBSM Competencies	Engine servicing, motorcycle electrical systems, workshop management	Technical diagnostics and damage analysis	Component assembly/disassembly; engine performance testing; customer service simulations
Learning Approach	PjBL, Inquiry, PBL	Promotes HOTS and applied creativity	Troubleshooting and efficiency improvement projects
Media / Module	Science process-based learning modules	Scientific, explorative, and reflective attitudes	E-modules for motor diagnostics; worksheets for performance analysis

The needs analysis results indicate that strengthening soft skills in physics learning must be linked to real-world practice, especially in vocational contexts such as TBSM. Learning that focuses solely on cognition is insufficient to build students' work readiness hence, project-based, inquiry-based, and problem-based approaches are essential (Mourato & Amaro, 2023). Through diagnostic and servicing activities, students apply the concepts of force, energy, torque, and electricity while developing critical thinking, decision-making, and technical communication skills. Workshop practices also cultivate collaboration and teamwork as 21st-century work competencies. Integration with simple entrepreneurial activities such as service simulations and cost calculations encourages responsibility, work ethic, and service orientation. Thus, this co-curricular model not only deepens conceptual understanding of physics but also prepares students to become adaptive and professional individuals in industrial environments, as shown in the following Table 2.

Table 2. Design of the Physics–Entrepreneurship Co-Curricular Program (TBSM Applied Model)

Program	Activity Focus	Physics Concepts	Soft Skills	Entrepreneurship
Brake & Suspension Diagnosis	Identify causes of poor braking and vibration	Force, momentum, pressure, vibration	Critical thinking, teamwork	Service reports & cost estimation
Engine Power & Efficiency Analysis	Test RPM, torque, and fuel consumption	Work, power, energy, efficiency	Problem solving, scientific communication	Service cost simulation & fuel-saving analysis
Ignition System Service	Check battery, spark plug, coil, CDI	Electric current, potential difference, circuits	Leadership, decision-making	SOP preparation & customer service
"Students Serve Students" Mini Workshop	Light service for school community	Application of integrated physics concepts	Collaboration, interpersonal communication	Pricing & service responsibility

Program analysis shows that co-curricular activities not only reinforce understanding of physics concepts but also build work competencies and student character. Brake diagnosis and engine efficiency projects offer opportunities for direct application of force, torque, and energy principles, which have been shown to enhance critical thinking and scientific process skills. Collaboration in the mini-workshop supports the development of communication and teamwork. Meanwhile, service simulations and cost calculations foster entrepreneurial orientation and work ethics, consistent with the idea that synergy between hard and soft skills is essential for modern work readiness. This program integrates physics as a scientific foundation, workshop practice as an applied context, and entrepreneurship as a reinforcement of professional character. The ultimate goal is for students not only to understand theoretical concepts but also to apply them appropriately, work collaboratively, make decisions, and demonstrate professional responsibility in alignment with the *Merdeka Curriculum*, as shown in the following Table 3.

Table 3. Analysis of Learning Objectives and Soft Skill Indicators

Co-Curricular Objectives	Physics Concepts	Practical Activities	Soft Skills	Key Indicators
Analyze brake and suspension malfunctions	Force, momentum, pressure, vibration	Brake and suspension diagnosis	Critical thinking, teamwork	Formulate hypotheses & work collaboratively
Calculate engine power and efficiency	Work, power, mechanical energy	RPM, torque, and fuel consumption tests	Problem solving, communication	Present results & explain concept–data relationship
Diagnose ignition and electrical systems	Electric current, potential	Battery, spark plug, coil, CDI service	Decision making, leadership	Identify faulty components & lead team activities

	difference, circuits			
Apply ethics in mini-workshop service	Cross-topic concept application	"Students Serve Students" practice	Collaboration, entrepreneurial mindset	Display professionalism & assess service value

The table shows that each co-curricular learning objective connects physics concepts with technical practices directly and meaningfully. In the brake and suspension diagnosis activity, students not only understand the concepts of force and momentum but also learn to identify damage causes through critical thinking. The measurement of engine power and efficiency encourages problem-solving and scientific communication as students present and discuss motor performance data. Additionally, electrical service and mini-workshop practices foster leadership, decision-making, and service orientation fundamental elements of entrepreneurial character formation. Therefore, learning functions not merely as knowledge transfer but as a transformative process for skills and work attitudes aligned with 21st-century demands. The research instruments were then designed to systematically document this transformation process through observation sheets, interview guides, and reflection rubrics assessing mastery of physics concepts, technical skills, and soft skill development. These instruments ensure that assessment focuses not only on cognition but also on character and students' work readiness, as shown in the following Table 4.

Table 4. Analysis of Research Instrument Development

Instrument	**Purpose**	**Assessed Aspects**	**Indicators**	**Instrument Items**
Workshop Observation Sheet	To observe students' engagement and application of concepts during practice	Collaboration, communication, discipline, physics application	Active participation in group work, use of physics terminology, adherence to SOP	Explains reasons for repair steps based on force and momentum
Student Interview	To explore conceptual understanding and learning reflection	Problem-solving, reasoning, teamwork	Relating malfunction symptoms to physics concepts; awareness of team roles	How do you identify the faulty ignition component?
Supervising Teacher Interview	To assess program effectiveness and group dynamics	Teacher guidance, team coordination, learning support	Teacher facilitates problem-solving and collaboration	How does group discussion assist in resolving technical problems?
Student Reflection Rubric	To assess professional awareness and service attitude	Self-evaluation, work ethics, business orientation	Recognizes strengths and weaknesses; works responsibly	What was the biggest challenge in today's workshop

practice and how did you solve it?

The table shows that each research instrument serves a complementary function in capturing the dynamics of learning throughout the co-curricular program. The observation sheet was used to examine the development of soft skills as students worked in teams, diagnosed mechanical problems, and applied physics concepts in hands-on workshop practice. Student and teacher interview guides explored thought processes and reflections on learning experiences, aligning with the reflective approach in science education. Meanwhile, the reflection rubric helped students recognize the interconnection between scientific concepts, technical skills, and work ethics essential for fostering an entrepreneurial mindset. Thus, the instruments not only assessed outcomes but also supported students' self-transformation into critical and collaborative independent learners. The instrument validation process was carried out through expert judgment by academic supervisors and field teachers to ensure the relevance, clarity, and measurability of indicators. This validation ensured that the instruments effectively captured the development of critical thinking, collaboration, communication, and entrepreneurial orientation in line with 21st-century learning needs, as shown in the following Table 5.

Table 5. Instrument Validation Analysis through Expert Judgment

Instrument	Validator	Validation Focus	Criteria	Results / Revisions
Workshop Observation Sheet	Physics Lecturer & Automotive Teacher	Alignment of indicators with objectives and workshop context	Concept relevance and behavioral measurability	The indicator "use of physics terminology" was clarified for easier observation
Student Interview	Educational Evaluation Lecturer	Clarity of reflective questions	Questions explore thought processes and experiences	Question wording revised to be more open-ended and less leading
Supervising Teacher Interview	Physics Teacher & Workshop Head	Context accuracy and instructional role	Exploration of group dynamics and teacher support	Added item on student engagement during service activity
Student Reflection Rubric	Character Education Lecturer & Guidance Counselor	Measurability of values and self-awareness	Clarity of assessment levels and indicator consistency	Added indicators "work responsibility" and "service orientation"

The validation process served not merely as an administrative step but ensured that each assessment indicator accurately reflected the objectives of the co-curricular program. Input from academic supervisors strengthened methodological accuracy, while physics teachers and workshop heads ensured field relevance (Ariani et al., 2016; Sultanova et al., 2021). Most revisions focused on clarifying the measurement of collaboration, scientific communication, and problem-solving core elements of context-based physics learning. The addition of entrepreneurial orientation indicators further emphasized the synergy between soft skills and hard skills essential for students' work readiness. Hence, the validated instruments were deemed valid, reliable, and relevant for assessing 21st-century competencies.

Implementation of the Co-Curricular Program

The co-curricular activity at SMA Negeri 2 Sandai was designed as a Project-Based Learning program over two months under the theme "Energy Efficiency and Innovation in Environmentally Friendly Workshop Practices." A total of 26 students from Grade XII Science (MIPA) worked in small groups facilitated by physics and automotive teachers. The activities were conducted through three stages: project planning, concept-based implementation in workshop practice, and reflective evaluation. This model enabled the integrated development of critical thinking, collaboration, scientific communication, and entrepreneurial orientation. Physics learning thus became more applied, contextual, and aligned with the demands of the modern workforce, as shown in the following Table 6.

Table 6. Analysis of Co-Curricular Program Implementation

Stage	Main Activities	Physics Concepts	Soft Skills	Instruments
Planning (Weeks 1–2)	Project design, role distribution, analysis of tools and cost requirements	Force, work–power, efficiency	Critical Thinking, Teamwork, Communication	Meeting observation & preliminary interview
Implementation (Weeks 3–6)	Engine diagnostics and light service focused on energy efficiency	Mechanical energy, torque, electricity, heat	Problem Solving, Decision Making, Leadership	Workshop observation & technical notes
Reflection & Presentation (Weeks 7–8)	Presentation of repair results and analysis of economic value of service	Integration of cross-topic physics concepts	Collaboration, Communication, Entrepreneurial Mindset	Reflection rubric & presentation assessment

The implementation of the co-curricular program demonstrated that the activities not only enhanced students' mastery of physics concepts and technical skills but also strategically developed their soft skills through experiential learning. During the planning stage, students identified problems and designed solutions, strengthening critical thinking and communication. Throughout the implementation phase, workshop practice facilitated the application of concepts such as power, torque, and efficiency while training problem-solving and decision-making skills (Zahara, 2018). The final reflection stage enabled students to evaluate their work process, internalize service ethics, and cultivate a basic entrepreneurial orientation (Rumerung et al., 2023b). Thus, the learning cycle successfully integrated scientific knowledge, practical skills, and character development in a systematic manner, as shown in the following Figure 1 and Figure 2.

Figure 1. Integrated Physics Teaching and Learning Activities with TBSM Concentration

Figure 2. Integrated Physics Practice TBSM Concentration

Observation results showed consistent student engagement in discussions, task distribution, and technical diagnostics. Students became increasingly capable of using scientific terminology, providing technical reasoning, and working cooperatively. The application of physics concepts was directly observed when measuring torque, adjusting ignition systems, and evaluating engine efficiency. At the same time, students demonstrated improved communication, collaboration, responsibility, and service-oriented awareness indicating that the learning process was meaningful and work-oriented, as shown in the following Table 7.

Table 7. Observation Results of Program Implementation

Aspect	Student Behavior	Soft Skills	Real Situation
Project Planning	Discussing and dividing tasks through deliberation	Critical Thinking, Collaboration	Role allocation according to each member's abilities
Workshop Service & Diagnostics	Conducting engine and electrical inspections with minimal guidance	Problem Solving, Decision Making	Selecting repair steps based on RPM testing and fuel consumption
Technical Group Discussion	Consulting and comparing test data results	Communication, Teamwork	Explaining torque changes after component replacement
Workshop Ethics & Work Discipline	Maintaining tools, cleanliness, and safety	Responsibility, Leadership	Reminding peers to wear gloves and follow workshop SOPs

Project Reflection & Presentation	Explaining processes, challenges, and outcomes clearly	Communication, Entrepreneurial Mindset	Offering a "fuel-efficient service" selling point

The analysis of observation results indicates that this co-curricular activity successfully linked physics concepts with real workshop practices. Diagnostic and service activities encouraged students to think critically, solve problems, and make data-driven decisions aligning with findings by Jayadi et al (2020) and Zahara (2018). Group dynamics also showed improvements in communication and collaboration, which are key 21st-century learning competencies. Furthermore, workshop service practices fostered work ethics, responsibility, and basic entrepreneurial orientation, supporting the idea that job readiness must integrate both hard and soft skills. Semi-structured interviews confirmed these findings. Students stated that project activities helped them understand the relationships between physics concepts such as force, torque, efficiency, and electricity and real technical situations in the workshop. They also reported improved teamwork, technical communication, and decision-making skills. Teachers observed that the program created more contextual, meaningful, and work-relevant learning, while simultaneously building students' professionalism and responsibility, as shown in the following Table 8.

Table 8. Results of Semi-Structured Interviews

Document Type	**Summary**	**Physics Concept Link**	**Observed Soft Skills**	**Main Findings**
Project Report	Objectives, procedures, torque and efficiency test results	Force, energy, power, mechanical efficiency	Critical Thinking, Problem Solving	Comparison of fuel consumption before and after service shows increased efficiency
Workshop Activity Photos	Service, calibration, and technical discussion practices	Application of physics concepts in real work	Teamwork, Communication, Leadership	Students collaborate during ignition system diagnosis
Individual Reflection	Narrative of experience, challenges, improvement strategies	Connecting theory with practical experience	Responsibility, Self-Awareness, Decision Making	Students realized the relationship between engine adjustment, RPM changes, and efficiency
Product/Innovation Documentation	Results of service and energy efficiency modifications	Integration of physics and automotive engineering concepts	Entrepreneurial Mindset, Service Orientation	"Fuel-efficient service" innovation

The analysis of interview results shows that this project-based co-curricular activity not only strengthened students' understanding of physics concepts but also encouraged the development of soft skills relevant to the workplace. Students learned to solve technical problems through discussion and data-driven measurement aligning with the characteristics of contextual science learning. Teachers observed that workshop practice provided opportunities for students to make decisions, coordinate, and communicate professionally essential competencies in vocational education. Moreover, entrepreneurial awareness emerged as students recognized the economic value of their services, reaffirming that physics can foster independence and local opportunity readiness. Supporting documents including project reports, workshop photos, and reflection notes provided authentic evidence of student engagement in designing, implementing, and evaluating activities. The reports demonstrated connections between physics concepts and engine service practices; the photos illustrated collaboration and compliance with SOPs; while the reflections highlighted the development of communication, responsibility, and service orientation. Collectively, these documents reinforced the observation and interview findings, confirming that meaningful and contextual learning occurred, as shown in the following Table 9.

Table 9. Supporting Documentation of Program Implementation

Document	Summary	Physics Concept	Observed Soft Skills	Main Findings
Group Project Report	Objectives, procedures, torque and efficiency results	Force, energy, power, mechanical efficiency	Critical Thinking, Problem Solving	Fuel consumption comparison table shows increased efficiency after service
Workshop Activity Photos	Documentation of service and technical discussion practices	Application of physics concepts in real work	Teamwork, Communication, Leadership	Students worked in coordination during ignition system diagnosis
Student Individual Reflection	Narratives of experiences, challenges, and solutions	Linking physics concepts with experience	Responsibility, Self-Awareness, Decision Making	"Efficiency changed after carburetor adjustment → theory–practice link proven"
Product/Innovation Documentation	Results of service and energy-efficiency modifications	Integration of physics and automotive engineering concepts	Entrepreneurial Mindset, Service Orientation	Prototype of a "fuel-efficient service" as a school workshop selling point

The analysis of supporting documents further confirms that this project-based learning successfully connected physics theory with authentic technical practice. The project reports demonstrated students' ability to interpret data and explain engine performance through simple scientific reasoning, reflecting enhanced critical thinking. Workshop photos revealed teamwork and active communication during practice, aligning with the importance of collaboration in contextual learning. Student reflection notes indicated growing responsibility and professionalism, while the documentation of energy-saving service innovations highlighted developing entrepreneurial orientation. Thus, the documents provided concrete evidence of students' growth in knowledge, attitude, and skills. To ensure data validity, this study employed technique and source triangulation by comparing the results of observations, interviews, and document analyses. This approach ensured that the findings accurately reflected real, consistent, and accountable learning processes, as shown in the following Table 10.

Table 10. Triangulation Analysis of Techniques and Sources

Type of Data	Source	Key Findings	Cross-Check	Conclusion
Participant Observation	Students' behavior and interactions during workshop practice	Students worked collaboratively, followed SOPs, and applied physics concepts	Consistent with photo documentation and project results	Learning behavior aligns with soft skills indicators
Semi-Structured Interviews	Students and teachers	Students understood the theory–practice relationship and showed improved responsibility	Reinforces observation findings on collaboration and problem solving	Internalization of concepts and work attitudes confirmed
Supporting Documentation	Project reports, activity photos, student reflections	Evidence of applying concepts of force, power, torque, and energy efficiency	Visually and textually supports observation and interview findings	Learning proven to be authentic and experience-based

The triangulation results indicate a strong alignment between students' observed behaviors in the workshop, their explanations during interviews, and authentic evidence from project reports and reflections. Observations recorded increased coordination and student engagement in diagnosing and repairing engines, which was confirmed through interviews when students explained the problem-solving process step by step and based on data. Project documents and activity photos demonstrated the real application of physics concepts in the workshop context, confirming that learning was contextual and practical. Meanwhile, student reflections showed growing responsibility and a service-oriented mindset, consistent with the importance of integrating hard and soft skills for work readiness. Data reduction was carried out by categorizing observation, interview, and document findings into soft skills themes such as critical thinking, collaboration, communication, problem solving, leadership, responsibility, and entrepreneurial mindset. The data were then organized into a thematic matrix to identify developmental patterns. Verification was conducted through discussions with mentor teachers, and validity was strengthened through member checking with students, in accordance with the principles of qualitative research credibility, as shown in the following Table 11.

Table 11. Thematic Matrix of Data Reduction Results

Soft Skill Theme	Observation	Interview	Supporting Documents	Development Pattern
Critical Thinking	Students analyzed engine faults before acting	Rationally linked torque–RPM relationships	Engine performance comparison table	Gradual analytical improvement
Collaboration	Students shared tasks and helped one another	Group work accelerated completion	Photos of service coordination	Stable teamwork after week 2
Scientific Communication	Discussions used technical terminology	Students more confident in explaining ideas	Presentations with machine test data	Scientific communication grew through practice
Problem Solving & Decision Making	Service steps based on test results	Technical decisions explained logically	Reflections show solution evaluation	Problem-solving improved through experience
Responsibility & Work Ethic	Discipline in SOP adherence and tool use	Students understood the importance of accuracy	Neat and clean work areas	Consistent work ethics across groups
Entrepreneurial Mindset	Efficiency considerations as basis for service	Students identified opportunities for eco-friendly services	Documentation of innovations and price estimates	Entrepreneurial awareness emerged during final reflection

The thematic matrix shows that students' soft skills developed progressively throughout the project. Critical thinking and problem-solving abilities improved as students linked engine malfunction symptoms with physics concepts such as force, torque, and efficiency during workshop practice. Collaboration and scientific communication grew through technical discussions and presentation of test results, aligning with the importance of teamwork in contextual learning. Responsibility and work ethics developed through adherence to SOPs and care for workshop tools. Meanwhile, an entrepreneurial mindset emerged as students recognized the potential of energy-efficient services as business opportunities.

Through member checking, students confirmed that these developments occurred naturally and were personally experienced during the project. A holistic assessment rubric was developed to evaluate learning achievement, encompassing understanding of physics concepts, technical skills, and soft skills such as critical thinking, collaboration, scientific communication, decision making, responsibility, and entrepreneurial orientation. The rubric design was based on observation, interviews, and project documentation, and referred to the objectives of the co-curricular program. Thus, the assessment measured not only knowledge but also character and work readiness, as shown in the following Table 12.

Table 12. Assessment Rubric for Integrated Physics Co-Curricular (TBSM)

Assessment Aspect	Key Indicators	Level 4	Level 3	Level 2	Level 1
Physics Concept Understanding	Relationship between force–energy–torque–efficiency and workshop practice	Clearly and consistently explains concept–practice connections	Explains concepts with partial practical examples	Understands concepts but struggles to connect to practice	Unable to explain concept–practice relationship
Diagnostic & Service Skills	Accuracy in analyzing damage and repair steps	Systematic diagnosis based on test data	Accurate diagnosis with teacher correction	Unstable diagnosis needing full guidance	Does not understand diagnostic procedures
Collaboration (Teamwork)	Active role and coordination in groups	Collaborates effectively and can lead	Active participation but inconsistent coordination	Passive participation, follows instructions	No participation in group work
Scientific Communication	Explaining technical reasoning and presenting data	Explains work and data systematically using technical language	Presents clear data but incomplete reasoning	Gives simple explanation without data support	Explanation unsystematic and unclear
Problem Solving & Decision Making	Data-based decision making	Independently makes data-driven decisions	Makes decisions after consultation	Decisions less accurate or not data-based	Decisions without analysis
Responsibility & Work Ethics	SOP compliance and tool maintenance	Always careful, maintains tools, follows safety standards	Occasionally needs reminders	Less careful and rushed	Ignores SOPs and safety
Entrepreneurial Orientation	Awareness of service value and innovation	Takes initiative in energy-efficient service innovation	Aware of limited business opportunities	Understands theory only	Shows no entrepreneurial awareness

This assessment rubric emphasizes that program evaluation assesses not only outcomes but also learning processes as part of holistic competency formation. Understanding of physics concepts is evaluated through their application in workshop practice, allowing students to learn through contextual experience. Collaboration and scientific communication develop through technical discussions and presentations, reflecting the importance of teamwork in 21st-century learning. Additionally, problem-solving ability, work ethics, and entrepreneurial orientation represent key aspects of modern vocational education and work readiness. Thus, the rubric provides a comprehensive overview of students' academic, technical, and character development. The assessment results reveal variation in students' soft skills achievements. Some students reached an excellent level in connecting physics concepts to practice, collaborating effectively, and making data-based decisions. However, others still required guidance, particularly in technical diagnostics, accuracy, and consistency of service orientation. These findings indicate that the program effectively enhances critical thinking, problem solving, collaboration, and work ethics, though continuous mentoring remains necessary to strengthen individual development, as shown in the following Table 13.

Table 13. Achievement Categories

Score Range	Category	Behavioral Interpretation Based on Rubric
90–100	Excellent	Demonstrates strong conceptual understanding, accurate diagnosis, effective collaboration, clear scientific communication, and initiative in practical efforts.
75–89	Good	Able to work in a structured manner but still needs improvement in consistency or independence in technical decision-making.
60–74	Fair	Understands part of the process but is not yet independent in diagnosis, communication, or teamwork.
< 60	Needs Guidance	Struggles to connect theory with practice and requires intensive direction in workflow and professional behavior.

The assessment results show variations in students' development of soft skills and mastery of physics concepts. Three students at Level 4 demonstrated a strong integration between theory and practice, data-based decision-making, collaborative leadership, and mature scientific communication. Level 3 students exhibited stable skills but still needed improvement in technical reasoning and independence when determining solutions. Meanwhile, Level 2 students understood basic concepts but were inconsistent in linking theory to practice and tended to be passive during group work. At Level 1, several students had difficulties in diagnosing malfunctions, adhering to SOPs, and demonstrating entrepreneurial orientation; therefore, they required gradual guidance and more structured learning. These findings highlight the importance of continuous contextual learning to strengthen the synergy between physics concepts, technical skills, and the development of professional character, as shown in the following Table 14.

Table 14. Results of Students' Soft Skills Assessment

No	Initials	Score	Category	Level	Summary of Key Behaviors
1	ANR	95	Excellent	L4	Understands the relationship between force–torque–efficiency; performs data-based diagnosis; leads collaboration; communicates clearly; innovative.
2	SAR	95	Excellent	L4	Presents scientific physics concepts; makes data-driven service decisions; disciplined in SOP; acts as group spokesperson.
3	ARD	93	Excellent	L4	Initiates "energy-saving service"; independent problem-solving; consistent work ethics.
4	LAB	85	Good	L3	Collaborates well; accurate diagnosis but incomplete technical explanation.
5	RAI	78	Good	L3	Consistent with SOP; needs guidance in decision-making and data presentation.

6	RSD	75	Good	L3	Completes tasks after consultation; collaborative but not yet taking initiative to lead.
7	TNN	73	Fair	L2	Understands basic concepts but hesitates to make decisions; limited communication.
8	PYJ	68	Fair	L2	Participates without initiative; unable to explain technical reasoning.
9–10	FAF, RZA	65	Fair	L2	Follows service procedures but struggles to present test data systematically.
11	ARS	63	Fair	L2	Fair collaboration; inconsistent scientific communication and work ethics.
12	AFR	58	Needs Guidance	L1	Unable to link test results with physics concepts; requires supervision.
13–14	SNR, VRK	53	Needs Guidance	L1	Low participation; diagnosis without data; lacks independence.
15	RDI	50	Needs Guidance	L1	Unstable work ethics; decisions not based on analysis.
16–18	ARP, NHN, RSS	48	Needs Guidance	L1	Weak coordination; lacks accuracy; no technical initiative.
19	AHZ	45	Needs Guidance	L1	Makes service decisions without further observation.
20–23	MRR, SLT, MPS, MIR	43	Needs Guidance	L1	Low communication and collaboration; minimal learning reflection.
24	MAH	40	Needs Guidance	L1	Unable to relate physics theory to practice; requires basic conceptual remedial work.
25–26	MHS, WLY	38	Needs Guidance	L1	Shows no service or entrepreneurial orientation; avoids technical discussion.

The findings indicate that high-achieving students were able to effectively integrate physics concepts, diagnostic skills, and collaborative work aligning with the results of Jayadi et al (2020), which emphasize the role of practice in developing critical thinking. Students in the Good category demonstrated strong potential but still needed reinforcement in independence and collaborative consistency. Conversely, students in the Fair and Needs Guidance categories required intensive mentoring, particularly in scientific communication, data-based decision-making, and workshop discipline, consistent with the recommendations of Sultanova et al (2021). Overall, the study confirms that soft skills development is progressive and requires continuous guidance to enhance students' work readiness and professional character.

Findings and Discussion

Thematic analysis of observational, interview, and document data revealed consistent patterns: (a) the physics concepts of force, torque, power, efficiency, and electricity were applied effectively in diagnosis/service; (b) core soft skills (critical thinking, problem-solving, scientific communication, collaboration, responsibility, leadership, and an entrepreneurial mindset) developed gradually throughout the workshop project cycle; (c) the best group performance demonstrated technical decisions based on test data (RPM/BBM) and coherent scientific narratives. These findings align with the characteristics of contextual and project-based science learning that encourage HOTS, scientific processes, and the transfer of concepts to practice. The dynamics of teamwork and presentations strengthen communication and collaboration, while the integration of workshop services fosters entrepreneurial orientation as a bridge between hard and soft skills.

Joint teacher-student reflection (evaluation of program effectiveness): The reflection session confirmed that the PjBL (Project Based Learning) themed "Energy Efficiency & Environmentally Friendly Workshop Business" effectively increased learning relevance and student agency: they were more confident explaining technical reasoning, documenting data, and making safe and efficient service decisions. Teachers assessed that engagement increased week by week, particularly in SOP compliance and role coordination. Areas of improvement identified were: consistency of technical justification in the "Good" category, strengthening scientific communication in the "Sufficient" category, and coaching on discipline and data analysis in the "Needs Coaching" category. The reflection results reinforce the idea that science should simultaneously shape character/soft skills and that hybrid PBL–inquiry learning enhances 21st-century strategic skills.

Recommendations for development & replication across schools: For implementation in other schools, we recommend: (1) scaffolded PjBL 2–3 cycles with explicit performance indicators (science concepts–processes–soft skills), (2) data-based diagnostic worksheets (RPM/BBM/torque test templates) and a short scientific communication rubric, (3) peer mentoring between students across achievement levels, (4) integration of mini-entrepreneurship incubations (service simulations, simple costing, service SOPs) to foster measurable entrepreneurial mindset growth, (5) regular expert talks from TBSM practitioners to strengthen industry relevance. This design aligns with evidence that cross-disciplinary projects (physics–automotive–business) simultaneously enhance technical and social competencies, while repeated project-diagnosis exercises strengthen HOTS and problem-solving skills.

Effectiveness of science–vocational integration: Research concludes that the integration of science (physics) and vocational learning (TBSM) effectively builds conceptual, technical, and soft skills competencies simultaneously, as evidenced by students' ability to link concepts to service actions, make data-based decisions, collaborate, communicate scientifically, and demonstrate work ethics and a service orientation. With a consistent PjBL/inquiry approach, this integration prepares graduates who are adaptive, solution-oriented, and professional, according to the 21st-century competency profile and industry needs.

4. Conclusion

This study concludes that integrating physics learning with Motorcycle Engineering and Business (TBSM) practices through project-based co-curricular activities effectively enhances students' conceptual, technical, and soft skills competencies. The best performance was demonstrated by three students (Level 4) who consistently linked the concepts of force–torque–efficiency with data-based diagnostics, led collaborative work, and communicated scientific ideas clearly. Some students reached Level 3, while those at Levels 2–1 require further coaching in diagnostic consistency, data communication, adherence to standard operating procedures (SOP), and entrepreneurial orientation.

These findings were validated through triangulation of observations, interviews, and documentation, and further reinforced by joint reflections between teachers and students, emphasizing the relevance of authentic tasks, adaptive mentoring, and reflective cycles. The model is suitable for replication with strengthened industry partnerships, peer coaching, and school-based mini-enterprise programs to ensure sustainability. Overall, the program fosters contextual and meaningful learning aligned with 21st-century demands, while preparing graduates to be adaptive, solution-oriented, and professional.

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