STEM Forward with Energy4Me: A Student-Centred, Industry-Linked STEM Outreach Project

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ABSTRACT

STEM Forward with Energy4Me was implemented as a student-centred STEM outreach project for secondary school students in Sabah. The original Energy4Me modules were externally developed and used as the technical activity base. The project contribution was the pedagogical orchestration of externally developed STEM modules into a student-centred, industry-linked learning experience. The project converted oil and gas concepts into an active learning format through Energy Trivia, five hands-on Energy4Me stations, the Peak Oil Game, career exposure, Q&A and survey-based reflection. The project design was informed by active learning, experiential learning, constructive alignment, inquiry-based science education and transformative learning (Prince, 2004; Kolb, 1984; Biggs & Tang, 2011; National Research Council, 2000; Mezirow, 1997). Reported outcomes indicated improvement in students' confidence in explaining oil and gas concepts, interest in oil and gas careers and familiarity with the industry. The project demonstrates how existing technical learning resources can be operationalised into a structured, evidence-informed STEM outreach model with measurable short-term impact.

Keywords: STEM outreach; Energy4Me; student-centred learning; experiential learning; oil and gas education; industry-linked learning; Sabah

PROJECT BACKGROUND

Many secondary school students encounter energy concepts through textbook-based science lessons, but opportunities to connect those concepts with authentic engineering and industry contexts are often limited. STEM Forward with Energy4Me addressed this exposure gap by translating oil and gas concepts into guided, hands-on learning activities. The project design was aligned with active learning principles, where students participate in meaningful learning activities rather than only receiving information (Prince, 2004).

The project was conducted on 24 September 2025 at Sabah State Library, Tanjung Aru Branch, involving 100 students from five schools in Sabah. The implementation was supported through university-industry-community collaboration involving Universiti Teknologi PETRONAS, ConocoPhillips, the U.S. Embassy, Energy4Me, the Society of Petroleum Engineers, Universiti Malaysia Sabah, Sabah State Library and school communities. STEM education literature emphasises the value of connecting STEM learning with real-world relevance, future workforce exposure and authentic problem contexts (Bybee, 2013).

The project was structured to shift the learner role from passive reception to active exploration. Students rotated through stations, observed physical demonstrations, interacted with facilitators and connected technical concepts with possible education and career pathways. This approach aligns with student-centred learning, where learner participation, responsibility and engagement become central to the learning process (Wright, 2011; Biggs & Tang, 2011).

PROJECT CONTRIBUTION

The Energy4Me modules were externally developed and are acknowledged as existing learning resources. The project contribution was not module ownership. The contribution was the technical and pedagogical arrangement of the modules into a complete outreach learning system. This included programme sequencing, contextualisation for Sabah students, facilitation structure, added engagement activities, career linkage and outcome analysis.

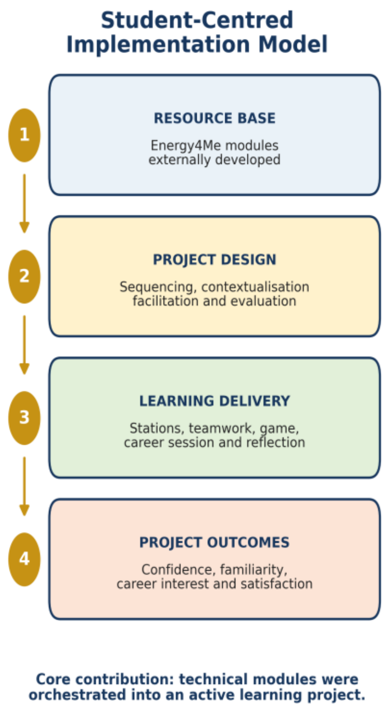

Figure 1. Student-centred implementation model for the Energy4Me project.

The contribution can be defined as pedagogical orchestration of externally developed STEM modules into a student-centred, industry-linked learning experience. This framing is technically accurate because it identifies the actual project work: designing the conditions under which learning occurred. Constructive alignment supports this framing because learning activities should be arranged to support the intended outcomes and evidence of learning (Biggs & Tang, 2011).

The resource base, project design, learning delivery and outcome indicators were connected into one implementation model. This approach avoided treating the modules as isolated activities. The modules were instead operationalised within a sequence that activated curiosity, enabled hands-on exploration, applied concepts through game-based challenge, linked learning to careers and captured immediate outcomes through survey feedback.

Figure 1 summarises the project contribution. The resource base consists of externally developed Energy4Me modules, while the project design layer represents the added value created through sequencing, contextualisation, facilitation and evaluation. The learning delivery layer shows how students engaged with the project, and the outcome layer links the implementation to confidence, familiarity, career interest and satisfaction. This structure is consistent with aligned educational design in which learning activities are connected to intended outcomes and evidence (Biggs & Tang, 2011).

LITERATURE AND TECHNICAL FOUNDATION

Student-centred learning provides the primary foundation for the project. Student-centred approaches shift the learning process away from one-way instruction and toward learner participation, dialogue, responsibility and meaning-making (Wright, 2011). The project applied this principle through station rotation, team-based activity, guided questioning, hands-on exploration and reflection.

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Active learning provides a second foundation. Prince (2004) defines active learning as instructional methods that engage students in meaningful learning activities and require students to think about what is being done. Freeman et al. (2014) reported, through a meta-analysis of STEM education studies, that active learning improves performance compared with traditional lecturing. Although the project was an outreach intervention rather than a formal academic course, the same principle applied: students were required to participate, observe, discuss and apply concepts (Prince, 2004; Freeman et al., 2014).

Experiential learning explains the pedagogical value of the hands-on stations. Kolb (1984) describes learning as a process where knowledge is created through the transformation of experience. The Energy4Me stations provided concrete experiences involving oil seepage, core sampling, lifting methods, perforated well casing and enhanced oil recovery. These activities enabled students to observe simplified technical processes before linking them to broader energy concepts (Kolb, 1984; Bransford et al., 2000).

Inquiry-based science education also supports the project design. The National Research Council (2000) describes inquiry as a process in which learners engage with scientific questions, evidence and explanation. During the station activities, students were not only shown technical explanations; students observed materials, discussed processes and asked questions about what was happening. This supported inquiry-oriented STEM exposure (National Research Council, 2000).

Transformative learning was used as a cautious outcome lens. Mezirow (1997) frames transformative learning as a shift in learners' frames of reference. The project did not claim permanent career transformation from a one-day intervention. Instead, the project treated increased confidence, familiarity and career interest as early indicators of perspective movement. Education for Sustainable Development was also relevant because the project supported quality education access and energy literacy, both of which align with UNESCO's ESD roadmap (UNESCO, 2020).

PROJECT DESIGN AND LEARNING FLOW

The project was arranged as a learning sequence rather than a set of disconnected activities. Students began with orientation and contextual introduction, followed by Energy Trivia or Kahoot to activate curiosity and prior knowledge. The main learning segment involved rotation through five Energy4Me stations. Students then participated in the Peak Oil Game, followed by a career journey session, Q&A and survey-based reflection. This sequence reflected constructive alignment by linking project objectives, activity design and evidence collection (Biggs & Tang, 2011).

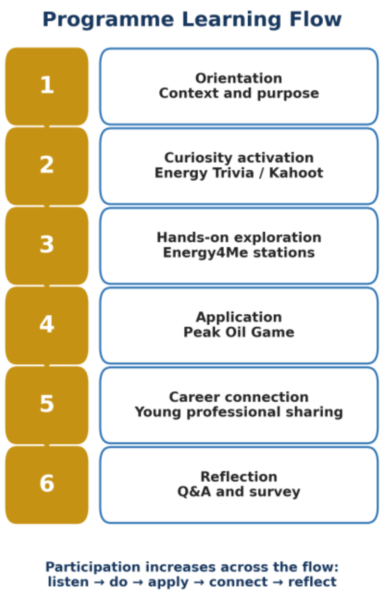

Figure 2. Programme learning flow from orientation to reflection.

Figure 2 shows how participation increased across the project. The project began with awareness, progressed to active exploration, moved into application through game-based learning, connected technical content to career

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pathways and concluded with reflection. This flow operationalised active learning because students repeatedly engaged with ideas through doing, discussing and applying (Prince, 2004; Freeman et al., 2014).

Table 1 shows that every component had a defined project function. The activity sequence was not only logistical; it was pedagogical. The table also supports replicability because the same technical structure can be adapted for other STEM themes such as sustainable energy, water treatment, chemical safety, environmental monitoring or robotics (National Research Council, 2000; Bybee, 2013).

Table 1. Programme design elements and student-centred value

Design component	Technical purpose	Student-centred value
Energy Trivia / Kahoot	Activate prior knowledge and curiosity	Students participate before technical delivery starts
Five Energy4Me stations	Provide hands-on exposure to oil and gas concepts	Students manipulate materials, observe outcomes and ask questions
Peak Oil Game	Apply concepts in a challenge-based format	Students make decisions, collaborate and solve problems in teams
Career journey session	Connect STEM activity to education and career pathways	Students link technical exposure with possible future aspiration
Q&A and survey	Consolidate learning and capture feedback	Student voice becomes part of the evidence of impact

IMPLEMENTATION EVIDENCE

The event photographs provide implementation evidence for the student-centred design. Visual documentation was included to show the physical learning environment, station-based engagement and facilitator-supported delivery. In active and experiential learning, the learning environment is important because participation, materials, questioning and peer interaction shape how students make sense of new concepts (Prince, 2004; Kolb, 1984).

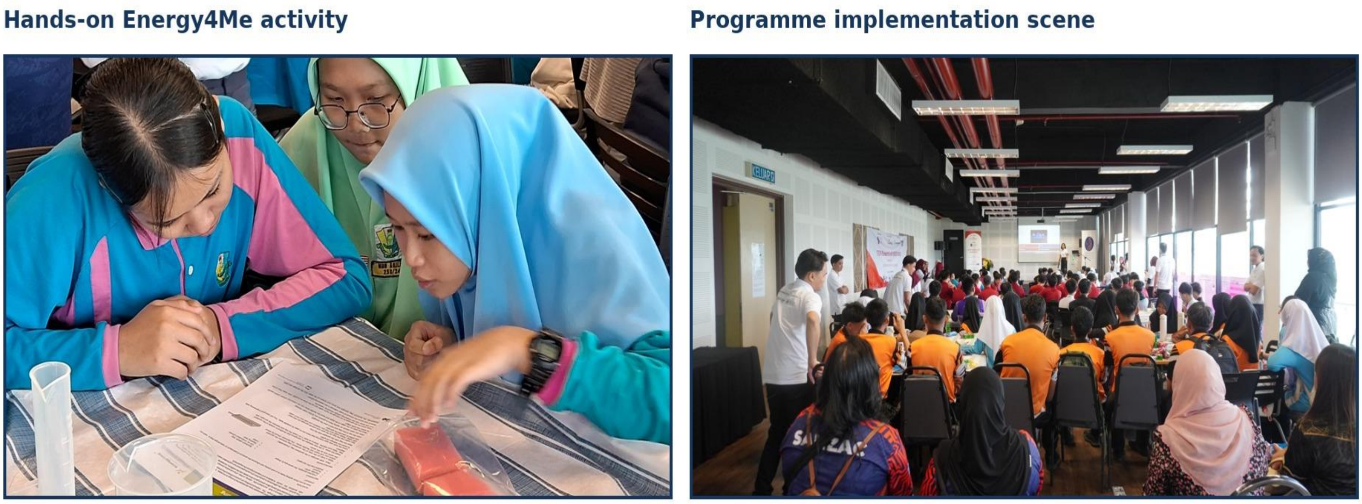

Figure 3. Event implementation scenes during the Energy4Me outreach project.

Figure 3 supports the implementation claim by showing that students were physically situated within activity spaces. The images complement the conceptual model and learning flow by demonstrating that the project was delivered as an active, station-based learning experience. This is consistent with inquiry-oriented STEM learning, where students engage with ideas through observation, guided exploration and discussion (National Research Council, 2000; Freeman et al., 2014).

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EVALUATION METHOD

The project used a programme evaluation approach based on available documentation and reported pre- and post-programme outcomes. The evaluation focused on immediate learning-related indicators rather than long-term tracking. Such an approach is appropriate when the objective is to assess the immediate value of a project intervention and to identify areas for future improvement (Biggs & Tang, 2011).

The analysis was descriptive because individual paired responses were not available in the current dataset. For that reason, statistical significance and effect size were not reported. Reported mean or percentage changes were interpreted as short-term indicators of project impact. This cautious interpretation ensures that outcome claims remain aligned with the available data (Bransford et al., 2000).

The selected indicators were confidence in explaining basic oil and gas concepts, interest in oil and gas careers, familiarity with the oil and gas industry and programme satisfaction. These indicators were appropriate because the intended project outcomes were conceptual exposure, career awareness, industry familiarity and student acceptance of the learning experience.

RESULTS AND TECHNICAL ANALYSIS

The strongest gain was observed in students’ confidence in explaining basic oil and gas concepts. The score increased from 2.50/5 before the project to 3.53/5 after the project. This gain suggests that the hands-on stations helped students connect unfamiliar technical concepts with observable activity. Learning research indicates that new knowledge becomes more meaningful when learners connect abstract ideas with concrete experiences and prior understanding (Kolb, 1984; Bransford et al., 2000).

Interest in oil and gas careers increased from 3.33/5 to 3.79/5. This increase should be interpreted as an aspiration signal rather than evidence of long-term career decision-making. Career direction is influenced by multiple factors beyond a single intervention. However, the gain suggests that career exposure and industry-linked activity may support early perspective movement, which is consistent with transformative learning theory (Mezirow, 1997).

Industry familiarity increased from 61.7% to 83.0%. This was a strong outreach outcome because one project objective was to expose students to oil and gas concepts and pathways. Overall satisfaction was reported at 4.81/5, indicating positive student acceptance of the learning experience. Satisfaction alone does not prove learning, but when considered together with confidence, career interest and familiarity gains, the results support the value of active, experiential STEM outreach (Prince, 2004; Freeman et al., 2014).

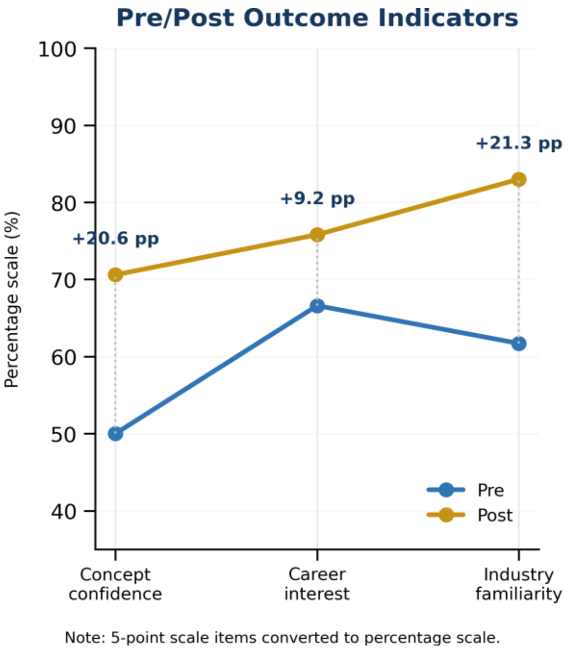

Figure 4. Pre- and post-programme outcome indicators.

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Figure 4 presents the project outcomes on a percentage scale. The largest percentage-point gain was observed in industry familiarity, followed by conceptual confidence. This pattern is technically consistent with the project design because the intervention was exposure-rich and activity-based. The outcome trend aligns with active learning research showing that student participation supports learning-related gains in STEM contexts (Freeman et al., 2014; Prince, 2004).

Table 2. Reported pre- and post-programme outcome indicators

Indicator	Pre	Post	Gain	Interpretation
Confidence explaining oil and gas basics	2.50/5	3.53/5	+1.03	Strong conceptual confidence gain
Interest in oil and gas careers	3.33/5	3.79/5	+0.46	Moderate but meaningful aspiration gain
Industry familiarity	61.7%	83.0%	+21.3 percentage points	Clear exposure and awareness gain
Overall satisfaction	-	4.81/5	-	High perceived value of the project

Table 2 provides the exact values used in the analysis. The data support immediate improvements in confidence, familiarity and career interest, while maintaining appropriate caution regarding long-term impact. This transparent interpretation strengthens the technical credibility of the evaluation (Bransford et al., 2000; Mezirow, 1997).

DISCUSSION

The findings are consistent with active learning literature. Prince (2004) emphasises meaningful student activity, and Freeman et al. (2014) reported improved student performance in active STEM learning environments. The Energy4Me project applied the same principle in an outreach setting by requiring students to observe, handle materials, discuss and apply concepts. The gains in confidence and familiarity therefore support the use of active learning beyond formal classroom delivery.

The findings also align with experiential learning theory. The Energy4Me stations provided direct experience, the facilitators supported explanation and the Peak Oil Game provided application. This sequence reflects Kolb’s (1984) learning cycle and supports the confidence gain observed after the project. Technical content became more accessible because students encountered concepts through simplified physical representations before connecting them to broader oil and gas processes.

The project also demonstrated inquiry-based STEM exposure. Students were guided to observe materials, ask questions and discuss technical processes. This aligns with the National Research Council’s (2000) emphasis on inquiry as a way of learning science through evidence and explanation. The career session further strengthened STEM relevance by connecting technical exposure to education and professional pathways, which is consistent with broader STEM education priorities (Bybee, 2013).

The transformative learning interpretation remained intentionally cautious. The project did not claim permanent changes in student career direction. The evidence supports a more defensible claim: the project created early shifts in confidence, familiarity and aspiration. Such shifts are consistent with Mezirow’s (1997) view that new experiences can influence frames of reference. The sustainability dimension was also treated as aligned value rather than measured outcome, reflecting UNESCO’s emphasis on education as an enabler of sustainable development (UNESCO, 2020).

REPLICABILITY AND IMPLEMENTATION LESSONS

The project model is replicable because it does not depend on expensive or highly specialised teaching infrastructure. The core requirements are a clear activity sequence, prepared facilitators, suitable learning materials, a safe activity space and a mechanism for collecting student feedback. This is consistent with active and inquiry-based learning, where the quality of participation and questioning is central to the learning process (Prince, 2004; National Research Council, 2000).

For future implementation, the same structure can be retained while changing the technical theme. The model can be adapted for sustainable energy, water treatment, chemical safety, environmental monitoring, robotics or other STEM themes. The consistent design logic is activation, exploration, application, career connection and reflection. This structure supports constructive alignment because activities remain linked to intended outcomes and evidence collection (Biggs & Tang, 2011).

Facilitator preparation is a critical success factor. The modules alone do not guarantee learning. Facilitators help students ask questions, interpret observations and connect activity outcomes with technical concepts. A short facilitator guide should be prepared for each station in future delivery, including learning outcomes, simplified technical explanations, anticipated student questions, safety notes and reflection prompts. Such preparation would improve delivery consistency and strengthen project scalability (Bransford et al., 2000).

LIMITATIONS AND FUTURE ENHANCEMENT

Several limitations were identified. First, the analysis was based on reported aggregate values and did not include individual matched pre- and post-programme responses. Therefore, statistical significance and effect size could not be calculated. Second, the outcomes represented immediate post-programme indicators and did not measure long-term retention, subject selection, university application or career decisions. Third, sustainability-related content was present, but sustainability outcomes were not measured separately.

Future implementation should collect paired student responses using anonymous codes. This would enable paired t-test, Wilcoxon signed-rank test and effect size calculation. Future surveys should also include open-ended reflection prompts to capture student voice and support thematic analysis. A follow-up survey after several months would strengthen the evaluation by indicating whether confidence, familiarity and interest were sustained over time (Mezirow, 1997; Bransford et al., 2000).

CONCLUSION

STEM Forward with Energy4Me demonstrated how externally developed technical modules can be operationalised into a student-centred, industry-linked outreach project. The project contribution was the pedagogical orchestration of Energy4Me modules through sequencing, contextualisation, facilitation, career exposure and outcome analysis. This approach was supported by active learning, experiential learning, constructive alignment, inquiry-based science education and transformative learning literature (Prince, 2004; Kolb, 1984; Biggs & Tang, 2011; National Research Council, 2000; Mezirow, 1997).

The results indicated immediate gains in conceptual confidence, industry familiarity and career interest. The figures and tables collectively documented the implementation model, learning flow, event evidence and outcome indicators. The project provides a replicable model for industry-linked STEM outreach where technical content is transformed into accessible, participatory and evidence-informed learning experience for school students.

ACKNOWLEDGEMENT

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