International Journal of Research and Review
[Indexed, Peer-Reviewed Journal]
Volume 12; Issue: 8; August 2025
Website: www.ijrrjournal.com
Research Paper E-ISSN: 2349-9788; P-ISSN: 2454-2237

Designing a Field-Based Environmental Problems (FBEP) Learning Model: Integrating Constructivist Theory and Experiential Learning

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DOI: https://doi.org/10.52403/ijrr.20250821

ABSTRACT

This study aims to develop a Field-Based Environmental Problems (FBEP) learning model that integrates constructivist theory and experiential learning within the context of higher education, specifically in the Environmental Chemistry course. The FBEP model is designed as a pedagogical framework to foster students' socio-scientific reasoning skills through direct engagement with real-world environmental issues encountered in the field. The model development was conducted within the Department of Chemistry, Faculty of Mathematics and Natural Sciences, Universitas Negeri Gorontalo, involving four expert validators as research participants. The instructional components developed include a semester learning plan (RPS), student worksheets (LKM), a field trip guide, interview protocols, and instruments for testing and observation. Expert validation focused on evaluating the model's relevance, content consistency, and theoretical construct. The validation results showed that the FBEP learning model was highly valid, with average scores of 95% for content and 93% for construct validity. These findings suggest that the FBEP model is suitable for instructional use and may be recommended for implementation in other courses that require a problem-based and field-oriented learning approach.

Keywords: FBEP learning model, constructivism, experiential learning, socio-scientific reasoning, expert validation

INTRODUCTION

Environmental issues such as climate change, water pollution caused by heavy metals, detergents, and pesticides are becoming increasingly severe and pose a tangible threat to the sustainability of human life (Madhav et al., 2020; Behera et al., 2024). Within this context, science education, particularly chemistry, is critical in equipping students with environmental awareness, sensitivity, and the ability to engage in socio-scientific reasoning (Georgiou & Kyza, 2023). However, environmental issues are often taught in isolation from students' real-life experiences. Traditional classroom settings tend to emphasize formal and theoretical instruction, which limits student engagement, reduces opportunities for critical thinking, and fails to foster a sense of responsibility toward environmental problems (Kinslow et al., 2018).

Many education scholars have recommended implementing outdoor or field-based learning to address these limitations, especially when contextualizing real-world environmental issues. This approach allows students to explore scientific content through direct experiences and authentic inquiry. Numerous studies have demonstrated that field-based environmental learning can positively impact students' cognitive, affective, and social skills (Dillon et al., 2006; Rickinson et al., 2004; Presley et al., 2013). Nevertheless, other research has noted that such learning models often fail to promote deep epistemic engagement and meaningful reflection. (Ryder & Leach, 1999; Burton, 2013).

In response to this gap, several researchers have attempted to design learning models that integrate scientific process skills with sociocultural perspectives in the study of environmental issues (Cooper, 2012; Sternäng & Lundholm, 2012). Although these approaches are promising, they often fail to genuinely engage students in critically working with their collected data or developing sufficient epistemological awareness. The Socio-Scientific Issues (SSI) approach has since emerged as a potential bridge to address this challenge by encouraging students to engage in complex reasoning, adopt a critical stance, and make informed decisions on real-world problems (Kinslow et al., 2018; Owens et al., 2019). These studies emphasize that when students deeply analyze environmental issues from multiple perspectives, their scientific reasoning becomes more critical, reflective, and personally meaningful.

Nevertheless, most existing models rarely systematically integrate environmental issues, content mastery, epistemic reasoning, and field-based experience. This gap is particularly evident in Indonesian education, where research that explicitly designs context-based instructional models based on theory and incorporates these elements remains limited. This study seeks to address that gap by developing a Field-Based Environmental Problems (FBEP) learning model that adapts principles from constructivist theory (Piaget, 1954; Vygotsky, 1978; Bruner, 2009), experiential learning (Kolb & Kolb, 2012), and project-based learning (Dewey, 1938). The FBEP model emphasizes authentic field experiences, collaborative inquiry, and the development of socially grounded, critical scientific reasoning.

This article focuses on the design phase of the FBEP learning model, elaborating on how theoretical principles are translated into practical instructional strategies. The research addresses how a learning model grounded in constructivist and experiential learning can be designed to support the development of students' socio-scientific reasoning skills in the context of environmental problem-solving.

MATERIALS & METHODS

This study employed a research and development (R&D) approach using a quantitative descriptive design. The objective was to develop a Field-Based Environmental Problems (FBEP) learning model that is valid, relevant, and appropriate for implementation in an Environmental Chemistry course. Product validation was conducted through expert feedback, using a model evaluation instrument.

Research Subjects and Setting

The study was conducted in the Department of Chemistry, Faculty of Mathematics and Natural Sciences, Universitas Negeri Gorontalo. The research subjects consisted of four expert validators who evaluated the design of the FBEP learning model. The validation assessed the model's relevance, content consistency, and construct coherence.

Research Procedure

The research procedure followed several sequential stages as outlined below:

Preliminary Study

A preliminary study was conducted to gather contextual information regarding the instructional setting, the need for model development, and relevant theoretical foundations. This phase involved multiple activities.

- Curriculum Analysis: This analysis was centered on the Merdeka Belajar Kampus Merdeka (MBKM) curriculum, with an emphasis on identifying relevant learning outcomes and evaluating the role of the Environmental Chemistry course in fostering students' critical thinking and socio-scientific reasoning skills.

- Course Characteristics Analysis: This stage focused on examining the cognitive, affective, and psychomotor competencies targeted within the course, particularly concerning thematic content concerning water quality and the ecological degradation of Danau Limboto as a contextual learning framework.
- Learning Model Evaluation: The study investigated the implementation of Case Study and Project-Based Learning (PjBL) models currently used in the course. The objective was to identify limitations and explore opportunities for enhancing the learning approach through a problem-based model rooted in real-world environmental issues.
- Student Profile Analysis: Data were collected to gain insights into students' learning styles, collaborative competencies, critical thinking abilities, and common challenges encountered during the learning process.
- Literature Review and Previous Research Analysis: This involved a comprehensive review of scholarly works on field-based learning models, constructivist and experiential learning theories, and the integration of Socio-Scientific Issues (SSI) as a pedagogical approach in science and environmental education.

Design of the FBEP Learning Model

Based on the findings from the preliminary study, the Field-Based Environmental Problems (FBEP) learning model was developed to provide a structured, field-based contextual learning experience. The model was designed to enhance students' socio-scientific reasoning skills through a systematic instructional syntax outlined in Table 1.

Table 1. Syntax of the FBEP Learning Model and Key Activities

Instructional Phase	Key Activities
1. Problem Presentation	Introduction to locally relevant environmental issues
2. Content Reinforcement and Project Design	Explanation of relevant scientific content and planning of fieldwork
3. Field Trip	On-site observation and data collection
4. Laboratory Analysis	Processing and analysis of field data
5. Results Reporting	Preparation of reports and presentation of findings
6. Assessment	Evaluation based on socio-scientific reasoning skills

The model integrates key principles from constructivist theory (Piaget, 1954; Vygotsky, 1978; Bruner, 2009), experiential learning (Kolb & Kolb, 2012), and project-based learning (Dewey, 1938). It is designed to foster students' active epistemic engagement through authentic field experiences.

Expert Validation

Three subject-matter experts subsequently evaluated the model using a Likert-scale instrument (1–5). The evaluation focused on the following criteria:

Theoretical coherence and alignment with the supporting frameworks

Clarity and logical flow of the instructional stages

Relevance of learning activities to the intended learning outcomes

Feasibility of implementation within the Environmental Chemistry course context

The expert assessment results were analyzed using descriptive quantitative methods by calculating the mean score for each criterion. These averages were then classified into levels of validity based on the interpretation scale presented in Table 2 below:

Table 2. Interpretation of Learning Model Validity Scores

Mean Score Range	Validity Classification
4.21 – 5.00	Highly Valid
3.41 – 4.20	Valid
2.61 – 3.40	Moderately Valid
1.81 – 2.60	Low Validity
1.00 – 1.80	Not Valid

Data Analysis Techniques

This study employed quantitative and qualitative descriptive analysis, synthesis techniques, and the Rasch Model approach. Quantitative descriptive analysis was used to evaluate percentage-based data from the validation of instructional tools, the implementation of learning activities, student engagement, and student responses through questionnaires. Meanwhile, qualitative descriptive analysis was applied to interpret expert validation data of the instructional model.

The Rasch Model approach was utilized to assess the validity, reliability, and sensitivity of the developed Field-Based Environmental Problems (FBEP) learning model.

Instructional Model Validity Analysis

The learning model and its supporting instruments were validated by expert reviewers using a validation rubric. The steps in the validity analysis were as follows:

Recapitulating expert scores based on evaluation criteria

Calculating the mean score for each criterion

Determining validity categories based on average scores using Ratumanan's (2003) classification scale:

85–100% = Very valid

69–84% = Valid

53–68% = Fairly valid

21–36% = Less valid

0–20% = Not Valid

The formula used to calculate the percentage of validity:

$$\% = \frac{\Sigma\ Average\ Score}{Maximum\ Score)}\ x\ 100\%$$

Model Reliability Analysis

Reliability was assessed using an inter-observer agreement approach based on the formula by Grinnell and Richard (1988). An instrument is considered reliable if the score exceeds 75%. Reliability Formula:

$$Percentage\ of\ Agreements(R) = \frac{d\bar{A}}{d\bar{A}+d\bar{D}}$$

Description:

$d\bar{A}$ = Number of agreements among reviewers

$d\bar{D}$ = Number of disagreements among reviewers

Item Sensitivity Analysis

This analysis evaluates how test items can distinguish between high- and low-performing students. The sensitivity formula (Okonkwo & Osuji, 2006) is as follows:

$$S = \frac{Rb - Ra}{T}$$

Description:

Ra = Number of students who answered correctly in the pretest

Rb = Number of students who answered correctly in the posttest

T = Total number of test-takers (average)

Items are considered sensitive if they exhibit a high and positive discrimination index, indicating effective differentiation of student abilities.

RESULT AND DISCUSSION

Needs Analysis for Learning Development

Learning Needs Analysis

Findings from the preliminary analysis indicate that the current Environmental Chemistry course has not provided sufficient opportunities for students to develop their socio-scientific reasoning (SSR) skills. The instructional approach remains largely traditional, relying on lecture-based methods with limited contextual engagement. Consequently, students are not adequately trained to critically analyze complex socio-scientific issues, such as environmental pollution and its broader ecological implications.

To address this gap, the FBEP learning model was developed with a structured sequence consisting of the following stages: (1) Problem Presentation, (2) Content Enrichment and Project Design, (3) Field Exploration, (4) Laboratory Analysis, (5) Reporting of Findings, and (6) Assessment (Kurnia, 2019; Alfiriani et al., 2017).

Student Analysis

The target learners for this model are undergraduate students enrolled in the Environmental Chemistry course, who exhibit diverse cognitive abilities and learning preferences. Initial classroom observations revealed that students tend to be less engaged during conventional discussion-based instruction and are generally unaccustomed to pedagogical strategies that require complex reasoning related to socio-scientific issues (Prasti & Kasma, 2020).

Hence, a learning model that incorporates field-based exploration and emphasizes the interpretation of real-environmental contexts is considered more appropriate to foster students' socio-scientific reasoning skills.

Learning Model Analysis

Instructional models such as Case-Based Learning and Project-Based Learning have effectively promoted higher-order thinking skills. However, these approaches have yet to explicitly accommodate the integration of socio-scientific contexts within the learning process.

The FBEP model was designed to bridge this gap by incorporating real-world, field-based experiences. It combines elements of problem-based learning with a socio-scientific issues (SSI) approach, encouraging active student engagement in investigating real-environmental problems.

Socio-Scientific Issue Analysis as a Learning Context

The contextual topic selected for the development of this model is *Pollution and Ecosystem Degradation of Danau Limboto*, which aligns with the subject matter of Environmental Chemistry, particularly water pollution and water quality. The socio-scientific issues were analyzed using a variety of sources, including documentary videos, online news articles, and scientific publications. Findings from this review revealed that Danau Limboto is facing a critical ecological crisis, driven by pollution, sedimentation, unsustainable fishing practices, and heavy metals and microplastics. These real-world issues were intentionally incorporated into the learning materials to foster students' environmental awareness and sensitivity, while also serving as a practical platform for developing socio-scientific reasoning skills.

The data sources utilized included YouTube videos depicting the lake's condition, news reports from Kompas and Mongabay highlighting pollution and threats to endemic species, as well as local research documents, such as the study by Krismono et al. (2017).

Learning Objectives Analysis

The analysis of learning objectives indicates that the intended outcome of developing the FBEP model is to enhance students' socio-scientific reasoning (SSR) skills. These objectives were formulated in operational terms to ensure they are measurable and achievable within the learning process. Students are expected to identify water quality issues linked to socio-scientific contexts, analyze the causes and consequences of these issues from both scientific and social perspectives,

conduct laboratory testing, and propose evidence-based solutions grounded in scientific principles and humanistic values. These goals are aligned with the learning outcomes of the Environmental Chemistry curriculum and reflect the demands of 21st-century education, which emphasizes critical thinking, creativity, and collaboration.

Design of the Field-Based Environmental Problem (FBEP) Learning Model

The FBEP model was strategically designed to address the limited student engagement in learning activities centered on socio-scientific issues. This was accomplished through the development of a comprehensive learning toolkit, including the semester learning plan (RPS), student worksheets (LKM), instructional scenarios, multimedia resources, field trip guides, interview protocols, and assessment instruments. These components aim to cultivate students' critical thinking and socio-scientific reasoning (SSR) skills through practical, field-based learning.

The RPS was constructed based on the FBEP syntax and structured across eight instructional sessions. Each session is designed based on specific learning outcomes, indicators, and time allocations, and is thematically focused on local environmental challenges. The learning process spans problem identification and field observation to laboratory analysis, reporting, and reflection. The core subject matter centers on the ecological degradation of Danau Limboto, offering comprehensive interdisciplinary content with both scientific and social dimensions

Table 3. Summary of the FBEP Model Lesson Plan for the Environmental Chemistry Course

Session	Course Learning Outcome (CLO)	Learning Activities	Indicators	Duration
1	CLO 1	Introduction to the SSI on Danau Limboto Water Pollution	Identifies SSI-related environmental issues	2x50 minutes
2	CLO 1	Analyzing causal relationships within the SSI context	Identifies causes, effects, and value conflicts	2x50 minutes
3	CLO 1	Designing a mini research project	Develops observation and interview instruments	2x50 minutes
4	CLO 2	Field trip and data collection	Conducts field observation, interviews, and documentation	2x50 minutes
5	CLO 2	Stakeholder perspective analysis	Analyzes opinions and differing viewpoints	2x50 minutes
6	CLO 3	Laboratory testing	Tests water quality and interpret results	2x50 minutes
7	CLO 4	Report writing and bias analysis	Proposes solutions and evaluates cognitive bias	2x50 minutes
8	CLO 4	Presentation and reflection	Presents findings and reflects on learning	2x50 minutes

In addition to the lesson plan (RPS), the Student Worksheets (LKM) were systematically developed to align with the instructional flow of the FBEP model. These worksheets are designed to guide students through active and reflective learning processes, starting from problem identification and field exploration to data-driven problem-solving.

Table 4. Structure of Student Worksheets (LKM) in the FBEP Model

Worksheet	Focus of Activity	Learning Objective
LKM 1	Identification of Socio-Scientific Issues	Students are able to identify complex socio-scientific problems
LKM 2	Orientation and Perspective-Taking	Students are able to analyze issues from multiple viewpoints
LKM 3	Mini Research Design	Students are able to design observation tools and interview instruments
LKM 4	Field Trip	Students are able to conduct field observations and document data
LKM 5	Laboratory Analysis	Students are able to analyze water samples and interpret the resulting data
LKM 6	Reflection and Solution Development	Students are able to formulate solutions and synthesize a final report

In addition to the RPS and LKM, a Socio-Scientific Reasoning Skills Test was developed to assess students' abilities in identifying, analyzing, and solving problems related to complex environmental issues. The test consists of 10 items, structured at two levels: multiple-choice questions (Q1) and essay questions (Q2), with the latter designed to explore students' arguments more deeply

This comprehensive design aims to ensure that learning is not limited to theoretical understanding, but also promotes higher-order thinking skills through real-world contexts closely tied to students' social and environmental realities. The FBEP model provides opportunities for students to construct knowledge through active engagement, field exploration, and data- and value-driven problem solving.

Validity Results of the Learning Model Development

The feasibility of the FBEP learning model was determined based on expert evaluations of the instructional components, including the RPS, learning materials, LKM, and assessment instruments. The evaluation used content and construct validation sheets to assess the relevance and consistency across components. Content validity focused on the alignment between indicators, objectives, and learning materials, while construct validity measured the extent to which the instruments captured the intended theoretical constructs.

The FBEP model was validated by four experts. The content validation covered aspects such as clarity of instructions, content quality, and language use. Expert feedback included suggestions to align the instrument objectives, adjust the validity rating scale, reinforce theories of social interaction, enrich learning resources (including videos, articles, and maps of Danau Limboto), and revise wording for clarity. On the other hand, construct validation emphasized the need for clear connections between instructional syntax, supporting theories, and learning system components such as media and social interaction during the learning process.

Table 5. Expert Comments and Suggestions on FBEP Validation Sheets

Validation Sheet	Assessed Aspect	Comments and Suggestions
Content	Instructions	The objectives and assessment criteria must be consistent; definitions of validity should be included in the theoretical framework.
Content	Content	Add theories of social interaction and learning resources from similar cases; include a map of Danau Limboto.
Content	Language	Use clear and communicative language; avoid ambiguity.
Construct	Instructions	Use LD, LDP, and TLD categories; clarify the assessment criteria.
Construct	Content	Add learning resources and an illustration of lecturer–student interactions.
Construct	Language	Correct typos and fix grammatical errors.

Revisions to the instructional tools were carried out based on expert feedback, which included adjustments to the instrument usage guidelines, a clear scoring scale, strengthening of theoretical foundations and learning resources, and editorial revisions. Following the revisions, the experts re-discussed and revalidated the tools.

Table 6. Expert Evaluation of the Content Validity of the FBEP Learning Model

No	Assessed Aspect	Average (%)	Category
1	Supporting Theories	93%	Highly Valid
2	Goal Rationality	95%	Highly Valid
3	Model Syntax	95%	Highly Valid
4	Social System & Response	90%	Highly Valid
5	Learning Environment	98%	Highly Valid
6	Instructional & Accompanying Impacts	95%	Highly Valid
7	Overall Validity of FBEP	100%	Highly Valid
	Average	**95%**	**Highly Valid**

All aspects of content validity were rated as highly valid, indicating that the FBEP learning model is appropriate for implementation in the context of environment-based problem learning. Follow-up comments from the FGD suggested refining the theoretical foundations that support the FBEP syntax, clarifying lecturer and student activities at each stage, and providing a more detailed field guide, including interview protocols adjusted to the local context, such as Danau Limboto. The evaluation also highlighted the need for consistency between the stages of analysis and laboratory testing procedures that are realistically feasible in the field.

Table 7. Summary of Expert Comments from the FGD

Aspect	Comments and Suggestions
Supporting Theories	Add references for each syntax stage; clarify the theoretical basis of the model
Objectives	Focus on measurable improvement of socio-scientific reasoning skills
Syntax	Add detailed learning activities; include interview guidelines and field trip guidelines
Social System	Enhance social interaction elements within the learning process
Support System	Include media and learning resources from similar case studies
Instructional Impact	The instruments are aligned with the intended learning objectives

The evaluation of model consistency also indicated a high level of validity. All assessed aspects received high scores, including the alignment between learning stages, objectives, content characteristics, learning activities, and the relevance of learning resources.

Table 8. Expert Assessment of Construct Validity of the FBEP Learning Model

No	Aspect Assessed	Average (%)	Category
1	Not contradictory to the learning objectives	95%	Highly Valid
2	Aligned with the learning objectives	95%	Highly Valid
3	Coherence between supporting theory and content	90%	Highly Valid
4	Understanding of SSI matches objectives and issue characteristics	95%	Highly Valid
5	Model phases support one another	95%	Highly Valid
6	Lecturer-student activities are interconnected	95%	Highly Valid
7	Learning resources support the achievement of objectives	95%	Highly Valid
8	Lecturer-student interaction patterns support the learning process	90%	Highly Valid
9	Lecturer's motivation is reflected in the model development	90%	Highly Valid
10	Activities support competency achievement	95%	Highly Valid
	Average	**93%**	**Highly Valid**

With average content and construct validity scores exceeding 90%, the FBEP learning model is considered highly valid and suitable for implementation as an innovative approach to developing students' socio-scientific reasoning skills.

Validity of the Semester Learning Plan (RPS)

The developed Semester Learning Plans (RPS) were designed to reflect the stages of the FBEP model while aligning with an Outcome-Based Education (OBE) curriculum. Based on expert validation, all RPS documents were rated as “Highly Valid (HV).” The evaluation covered several key components, including the formulation of learning objectives, content alignment, language clarity, time allocation, and learning activities. The average validity scores ranged from 94% to 100%.

Table 9. Expert Evaluation Results for the Semester Learning Plan (RPS) Based on the FBEP Learning Model

Evaluated Aspect	RPP 1	RPP 2	RPP 3	RPP 4	RPP 5	RPP 6
Learning Objectives	96% (HV)	96% (HV)	96% (HV)	98% (HV)	96% (HV)	98% (HV)
Content	100% (HV)	100% (HV)	100% (HV)	100% (HV)	100% (HV)	100% (HV)
Language Clarity	94% (HV)	100% (HV)	100% (HV)	100% (HV)	100% (HV)	100% (HV)
Time Allocation	94% (HV)	100% (HV)	94% (HV)	100% (HV)	94% (HV)	94% (HV)
Learning Activities	94% (HV)	95% (HV)	95% (HV)	96% (HV)	97% (HV)	97% (HV)

Validity of Student Worksheets (LKM)

The developed student worksheets (LKM) were designed to align with the activities embedded in the environmental problem-based learning approach. Expert validation confirmed that the LKM is highly valid (HV) across all evaluated aspects, including the clarity of instructions, alignment of objectives, and content relevance. The average scores ranged from 95.8% to 100%.

Table 10. Validation Results of Student Worksheets (LKM)

Aspect Assessed	LKM 1	LKM 2	LKM 3	LKM 4	LKM 5	LKM 6
Instructions	100% (HV)	100% (HV)	100% (HV)	93.8% (HV)	100% (HV)	100% (HV)
Objectives	87.5% (HV)	93.8% (HV)	100% (HV)	93.8% (HV)	100% (HV)	100% (HV)
Content	100% (HV)	100% (HV)	100% (HV)	100% (HV)	100% (HV)	100% (HV)

Field Trip Guide Validity

The field trip guide represents a core component of the FBEP learning model. Validation focused on several aspects, including the clarity of instructions, alignment of objectives, and content relevance. All aspects were rated highly valid, with the highest score reaching 100%.

Table 11. Expert Evaluation of the Field Trip Guide

Evaluation Aspect	Mean Score	Percentage	Description
Instructions	4.00	100%	Highly Valid
Objectives	3.75	93.75%	Highly Valid
Content	3.75	93.75%	Highly Valid

Interview Guide Validity

The interview guide was developed to assist students in collecting data from community members and relevant stakeholders. Four key aspects were evaluated for validity: instructions, objectives, content, and language. The validation results indicated that all aspects met the criteria of being "Highly Valid."

Table 12. Expert Validation Results of the Community Interview Guide

Assessment Aspect	Mean Score	Percentage	Description
Instructions	4.00	100%	Sangat Valid
Objectives	4.00	100%	Sangat Valid
Content	3.75	93.75%	Sangat Valid
Language	3.75	93.75%	Sangat Valid

Overall, the validation of the instructional tools developed using the FBEP model demonstrated highly satisfactory results. All components were rated highly valid and deemed appropriate for trial implementation and actual classroom application. These validation outcomes reinforce that the FBEP model has been consistently integrated across instructional components and effectively supports the development of students' socio-scientific reasoning skills.

CONCLUSION

Based on the validation conducted by four expert validators, all instructional instruments developed under the Field-Based

Environmental Problem (FBEP) learning model have been considered highly valid. The semester learning plans, student worksheets, field trip guide, and community interview guide have all met the criteria for content relevance, objective alignment, clarity of instructions, and language appropriateness. These findings indicate that the FBEP model has been effectively integrated into the instructional components supporting students' socio-scientific reasoning skills. The high validity in both content and construct also reflects the model's strong theoretical foundation and the internal consistency across its instructional syntax.

Therefore, it is recommended that the FBEP learning model and its accompanying instructional instruments be broadly implemented in educational settings, particularly in courses that address environmental and socio-scientific issues. It is also essential to conduct guided trials across diverse learning contexts to enhance the quality of future implementations. Additionally, the development of a more comprehensive technical guide is necessary to ensure that both lecturers and students can fully understand and effectively carry out each phase of the FBEP model.

Declaration by Authors

Acknowledgement: None

Source of Funding: None

Conflict of Interest: No conflicts of interest declared.

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How to cite this article: Julhim S. Tangio, Ramli Utina, Frida Maryati Yusuf, Lukman Abdul Rauf Laliyo, Weny Musa, Masrid Pikoli. Designing a field-based environmental problems (FBEP) learning model: integrating constructivist theory and experiential learning. *International Journal of Research and Review*. 2025; 12(8): 186-196. DOI: *https://doi.org/10.52403/ijrr.20250821*

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