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Developing an inquiry-based STEAM teaching packet in ecoliteracy for pre-service teachers

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ABSTRACT

Education plays a vital role in addressing the current environmental crisis. Integrating ecoliteracy in teacher preparation programs empowers colleges and universities to promote a healthy biosphere by producing pre-service teachers (PSTs) who can develop an ecoliterate student citizenry. Connectedly, ecoliteracy must be taught to PSTs through effective and meaningful learning experiences. Using the research and development (R&D) design, this study aimed to develop a teaching packet that incorporates inquiry-based learning (IBL) and science, technology, engineering, arts, and mathematics (STEAM) education to foster ecoliteracy among PSTs. Focus group discussion (FGD) results revealed an opportunity to craft the teaching packet. Ecoliteracy conceptualizations guided the formulation of the packet's learning outcomes and topics. Eight (8) evaluators assessed the packet's preliminary version, which satisfied 74% of the indicators in the adapted evaluation tool. After implementing the packet to 38 PSTs, findings reveal a statistically significant increase in conceptual understanding and ecoliteracy levels. Both PSTs and faculty members share positive perceptions towards the teaching packet, though they also suggested further improvements to the material. Overall, the results document the potential of IB-STEAM in fostering PSTs ecoliteracy, showing how innovative and integrative pedagogies are instrumental for effective ecoliteracy instruction in teacher education.

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1. INTRODUCTION

In the past years, environmental education (EE) has been incorporated into the curriculum to respond to the present-day environmental crisis. However, EE has been criticized for not yielding substantial gains despite its financial investments [1]. We continue to see various environmental problems across scales, levels, and contexts. The poor implementation of EE in our schools is linked to teacher's lack of self-confidence and experience, use of traditional teaching methods, and forced compliance to curriculum requirements [2]. Furthermore, while modern education teaches about the planet's natural systems, learning typically develops from a materialistic worldview [3]. This presented scenario eventually redounds to the competence of teachers as they are the primary implementers of EE.

Teachers play a vital role in ensuring a well-rounded citizenry that displays a deep understanding, profound concern, and responsible behavior for the environment [4]. Accordingly, their pre-service training years must enable them to acquire ecological literacy or ecoliteracy competencies to produce a heightened awareness, concern, and responsibility toward nature [5]. Ecoliteracy involves understanding the principles behind the organization and processes of natural systems and applying such understanding in organizing sustainable human communities [6]. It provides a framework for systems thinking, enabling us to map relationships in the entire web of life [6]. Cutter-Mackenzie and Smith [7] iterates that a nominal level of ecological literacy among teachers is insufficient to produce an ecoliterate student citizenry.

Studies have documented compelling and conflicting findings on pre-service teachers (PSTs) ecoliteracy or environmental literacy levels. It was revealed that while PSTs have positive environmental attitudes, they have moderate environmental knowledge and limited participation in environmental initiatives [8]. Biology PSTs were found to have inadequate environmental knowledge and analysis, though they have favorable attitudes toward the environment [9]. It was also reported that PSTs were unaware of environmental policies and issues, though they were moderately participative in environmental activities [10]. While PSTs may demonstrate ecological awareness, it does not necessarily equate to deep or actual understanding [11]. The findings suggest to further deepen PSTs' ecoliteracy, which is aligned with the call to integrate it as a critical skill for all students and professionals [12]. Since ecological empowerment is still a challenge in schools [13], we need teacher educators and classroom teachers ready to educate about ecoliteracy [14], especially since not many teachers have the expertise to teach about it [15].

To augment PSTs' ecoliteracy, they must be engaged in meaningful learning experiences through effective teaching-learning materials. Previous studies have explored the development of innovative materials to provide such experiences. In basic education, picture books, localized materials, and modules have been crafted, which were valid and empirically effective [16]–[19]. However, few studies have explored instructional materials development in ecoliteracy for teacher education. Environment-based teaching materials improved PSTs' ecoliteracy [20], while a web-based biotechnology module also produced similar results [21]. Hence, the potential to further explore this area remains open, especially by embedding appropriate pedagogies for ecoliteracy. In teaching ecoliteracy, it is suggested to use cognitive, pragmatic, creative, and multidisciplinary means [22]. In the Philippines, teacher education programs recently included the teaching of ecoliteracy through the subject "Building and Enhancing New Literacies Across the Curriculum" (BENLAC) [23]. The subject similarly prescribed using "field-based interdisciplinary explorations" in teaching ecoliteracy [24].

Connectedly, two relevant pedagogies for teaching ecoliteracy are the 7E's learning cycle of inquiry-based learning (IBL) and the science, technology, engineering, arts, and mathematics (STEAM) education model. IBL can provide pragmatic or hands-on learning in field-based settings. STEAM education promotes inter/multidisciplinarity and creativity in addressing real-life issues. Both IBL and STEAM education can develop the cognitive skills of the PSTs. Moreover, the integration of STEAM in PST education is aligned with Hong's [24] suggestion of extending its implementation from basic education to university education. Hence, these two pedagogies can develop PSTs' ecoliteracy. Eventually, this will contribute to the achievement of large-scale programs, most especially the biosphere-related Sustainable Development Goals.

Existing literature shows the potential of IBL and STEAM education, especially in integration for ecoliteracy. Studies have utilized IBL to foster ecoliteracy and similar educational goals [25], [26]. Under mixed online learning, the 7E's learning cycle of IBL had positive impacts on the produced positive effects to students' performance, attitude, engagement, and efficacy in learning college environmental science concepts [27]. STEAM education can also be integrated with the environmental concept with its ability to improve creative thinking [28]. The 7E's learning cycle of IBL and its 5E's predecessor were also used as primary instructional design frameworks for science lessons, wherein relevant STEM/STEAM disciplines were suitably incorporated in certain stages of the cycle [29], [30]. However, the integration of 7E's learning cycle of IBL with STEAM education in higher education has not yet been explored, particularly for ecoliteracy.

This study aimed to incorporate the 7E's learning cycle of IBL and STEAM education model in crafting a teaching packet to foster the ecoliteracy of PSTs. A teaching packet is an instructional material intended to guide a higher education faculty member in delivering its lessons, which includes prescribed teaching strategies/techniques, topics/concepts for discussion, learning activities, and other important details. To evaluate the inquiry-based (IB)-STEAM teaching packet's effectiveness and how it can be improved, this study sought to address the following specific objectives:

i) Compare the conceptual understanding scores and ecoliteracy levels of PSTs' before and after using the IB-STEAM teaching packet.
ii) Determine the perceptions of PSTs and faculty members after the implementation of the IB-STEAM teaching packet in ecoliteracy.

2. METHOD

2.1. Research design

This study used the research and development (R&D) design to produce an IB-STEAM packet for teaching ecoliteracy. R&D design focuses on crafting educational products or services to improve school curriculum, instruction, and evaluation practices in schools [31]. This study collected data before developing the IB-STEAM packet for benchmark information served as valuable inputs for relevant and practical teaching material. Before and after the implementation of the teaching packet, data were collected to determine the impact of the material and its needed modifications. Thus, this study also embedded the quasi-experimental pretest-posttest design with qualitative supporting data for triangulation during the packet's implementation.

2.2. Participants

The primary respondents of this study were PSTs from a teacher education institution (TEI) in Leyte, Philippines. These PSTs were officially enrolled in the BENLAC subject for the 2nd Semester, S.Y. 2022-2023. However, due to feasibility limitations, only one class was involved, composed of 38 PSTs. Teachers or faculty members were also involved during certain phases of the study, specifically needs analysis, preliminary evaluation of the IB-STEAM teaching packet, and observation of field testing/implementation. These teachers or faculty members are either/both specializing in science education or have handled the BENLAC subject in the previous semesters/school years. Specifically, three (3) faculty members observed the implementation of the IB-STEAM teaching packet.

2.3. Research instruments

To gather the needed data for this study, the research instruments used were i) an instructional material evaluation tool, which includes the following indicators: quality of content, teaching-learning tool, ease of use, format, similarity index, and language conventions; ii) a pretest-posttest instrument to assess the changes in PSTs' conceptual understanding of ecoliteracy, which was validated through item analysis; iii) the ecoliteracy scale developed by Okur-Berberoğlu [32], which captures other essential aspects/subscales of ecoliteracy; and iv) perceptions questionnaire, which was used to gather the overall perceptions of PSTs and teachers after the IB-STEAM teaching packet had been delivered. It has two versions. For the PST respondents, this instrument has two parts: the seven-point Likert scale of activity perceptions questionnaire (APQ) by Deci *et al.* [33] and a series of open-ended questions. For the teachers' version of the questionnaire, they only answered the open-ended questions, which were contextualized to their role in the study.

2.4. Data collection

The flow of steps in this study is a relatively more straightforward or modified version compared to the steps laid initially by Borg and Gall for R&D design because of practical limitations on time and available respondents for the study in the research site. Other researchers in the past decades have also modified the original framework to suit the contexts of their respective investigations [30]. Figure 1 summarizes the series of steps taken in this study.

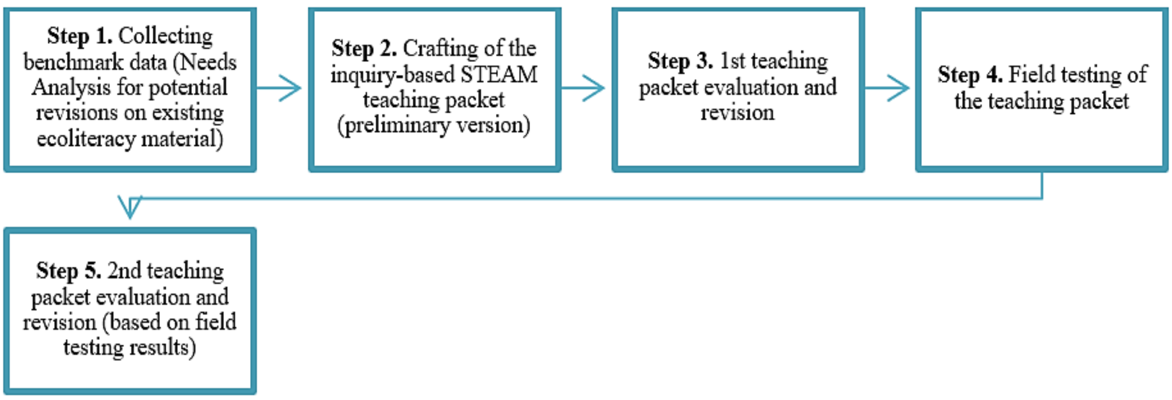

Figure 1. Flowchart of steps in the study

2.5. Data analysis

Descriptive statistics were used to analyze the data for the pretest-posttest scores, ecoliteracy pre-instruction and post-instruction results, and APQ data. Regarding inferential statistics, the data were tested for normality first to determine whether to use a parametric (t-test) or a non-parametric counterpart (Wilcoxon signed rank test) for significant differences. The perceptions and other relevant comments and feedback from PSTs and faculty members were processed through thematic analysis to identify the recurring patterns and commonalities among their responses [34].

3. RESULTS AND DISCUSSION

3.1. Needs analysis and preliminary product development

This study sought to develop a teaching packet to foster the ecoliteracy of PSTs. Previous studies have shown the need to augment the ecoliteracy of PSTs, which can be done by utilizing relevant pedagogies. Very few studies have explored ecoliteracy instruction for teacher education, and none have previously utilized IBL and STEAM education to teach ecoliteracy to PSTs. This study begins with a needs analysis, specifically through a focus group discussion (FGD) that elucidated eight (8) questions on revisiting the existing ecoliteracy material in the participating school. The following are the major findings uncovered, which were used to guide the process of making the teaching packet:

i) Preference to experiential activities in the existing material. All participants preferred activities that required engagement and hands-on involvement among the PSTs. This helps the PSTs practice ecoliteracy skills and provides authentic choices on demonstrating their learning. This is highly consistent with the transformative learning theory, specifically on directly applying knowledge and values to bridge the gap between knowledge and action [35].
ii) Preference to assessments with reflection and higher-order thinking skills (HOTS). Participants preferred those assessments that involve self-reflection and HOTS, which seems to be lacking in the existing ecoliteracy material. Evaluation of the HOTS level is necessary to determine whether the PSTs have attained the expected level of ecoliteracy that they must have.
iii) Recognizing areas for improving/enhancing the existing material. Participants recognized that it can still be improved or enhanced for better learning of the PSTs. These enhancements generally pertained to making the material more suitable to the present time and the demands of the teaching profession, such as updating the content, contextualizing topics, integrating ecoliteracy pedagogies, and expanding the scope of learning activities.

A literature review was also conducted on the conceptualizations of ecoliteracy to guide the framing of the learning outcomes of the IB-STEAM teaching packet, especially the works of the Center for Ecoliteracy [36] and Okur-Berberoğlu [32]. The reviewed conceptualizations complemented the FGD themes and augmented what the PSTs can learn and experience about ecoliteracy. Since the teaching packet will be used for the professional learning of PSTs, relevant topics such as green schools, green curriculum, and ecoliteracy teaching strategies were also included [37]. Considering feasibility in terms of time, two lessons were finally prepared for the teaching packet.

In keeping with Borg and Gall's R&D design, this study also formulated a framework that underpins the basis, structure, and overall goal of the IB-STEAM teaching packet, as shown in Figure 2. It illustrates that certain STEAM disciplines are infused into certain learning cycle stages whenever appropriate, which is largely based on previous studies [29], [30]. The formulated framework shows the interfacing of the 7E's of IBL and STEAM education model to provide learner-centered and rich experiences in teaching ecoliteracy. Table 1 shows how the STEAM disciplines are evident across the two lessons of the teaching packet. There are two criteria used in deciding the activities in the teaching, namely i) each activity/instructional strategy must be aligned to the specific stage of the 7E's learning cycle where it is placed and ii) the entire lesson must embody all of the STEAM disciplines.

3.2. Instructional materials evaluation results

This stage helps judge the preliminary product's worth and how it can be holistically refined. Table 2 summarizes the number of indicators/sub-indicators satisfied among the five criteria in the adapted evaluation tool. The preliminary teaching packet satisfied most of the indicators/sub-indicators in the tool, which is an initial manifestation of the potential of the IB-STEAM teaching packet to increase PSTs' ecoliteracy. Such is observed in a similar instructional materials development study for ecoliteracy for high school students [38]. Moreover, based on the cognitive load theory (CLT), the findings in Table 2 generally show that the teaching packet meets the instructional recommendations for students' learning. However, approximately 26% of the indicators/sub-indicators were not adequately satisfied, which implied minor and major revisions. For the content, revisions were generally focused on streamlining the content, consistency in referencing styles, and contextualizing graphics. For the function as a teaching-learning tool, revisions were mostly on improving the instructions for the different activities. There were fewer revisions for the criteria on ease of use, format, similarity index, and language conventions. Based on Vygotsky's sociocultural theory, these improvements further support the faculty member as a more knowledgeable other (MKO) in teaching ecoliteracy.

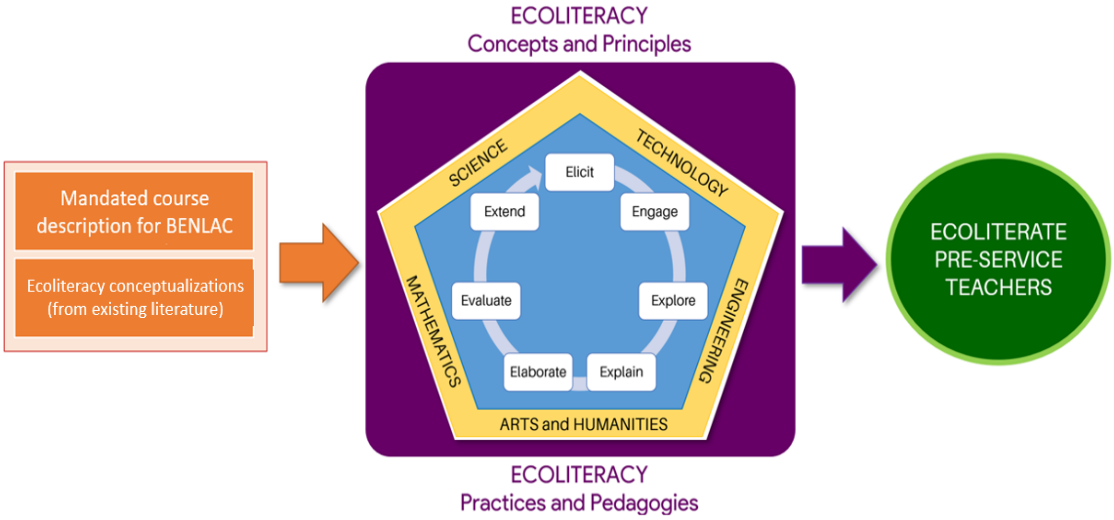

Figure 2. Instructional design framework combining 7E's of IBL and STEAM education model

Table 1. Integration of STEAM disciplines in the teaching packet

STEAM disciplines	Lesson 1	Lesson 2
Science	Discussion of scientific concepts and principles about ecoliteracy, as well as systems thinking	Discussion of ecological living practices (sustainable lifestyle, green consumerism)
Technology	Use of non-electronic tools during the making of the students' systems thinking concept map, use of electronic gadgets for research and to capture photos of environmental principles	Use of electronic/non-electronic tools in making their green school plan, for research, and in designing and executing their environmental action plan
Engineering	Crafting the concept map/mind map flat model to show systems thinking of society, economy, and nature (process flow: identifying the task's goal, brainstorming on possible connections, developing the systems thinking map, refining/optimizing the map)	Designing the green school plan; crafting and implementing their environmental action plan (e.g., involves making a beneficial material/product or innovative use of space)
Arts	Incorporation of creativity in the crafting of systems thinking map, integration of photography as visual arts in recognizing/observing environmental principles	Incorporation of creativity in the designing of envisioned green school concept, as well as in their environmental action plan
Mathematics	Incorporation of shapes and measurements in crafting the systems thinking map	Calculating ecological footprints, measurements on the dimensions of their green school plan

Table 2. Summary evaluation of the teaching packet's preliminary version

Criteria	No. of indicators satisfied with 100% "Yes" agreement	Equivalent percentage
Quality of content	7 out of 9	77.78
Teaching-learning tool	6 out of 8	75
Ease of use	2 out of 5	40
Format	4 out of 5	80
Similarity index and language conventions	4 out of 4	100
Total	23 out of 31	74.19

3.3. Gains in conceptual understanding and ecoliteracy level

Comparing the pre- and post-implementation results of the IB-STEAM teaching packet shows improvement in the PSTs' conceptual understanding. As shown in Table 3, the PSTs' mean score increased from the pretest to the posttest. The results of the paired samples t-test for the pretest-posttest scores in conceptual understanding also indicate that the null hypothesis is rejected. There is a significant difference between the PSTs' pretest and posttest scores before and after implementing the teaching packet in ecoliteracy. Interestingly, the standard deviation (SD) shows that the pretest scores are more homogenous compared to their posttest scores, which implies that the PSTs' baseline level is more consistent. The increase in the SD means that the achievement of the PSTs became more dispersed after the implementation of the IB-STEAM teaching packet, indicating that the extent of positive effects produced by the material varied differently among the PSTs, with some having higher improvements compared to others. Furthermore, the effect size for this analysis (Cohen's d=1.35) exceeded Cohen's convention for a large effect.

Table 3. Paired t-test for pretest-posttest scores in the conceptual understanding test

	Mean	SD	Mean difference	t-statistic	df	P	SE diff	Cohen's d
Pre	9.50	3.27	6.92	8.30	37	<0.001	0.833	1.35
Post	16.42	4.16						

Similar to conceptual understanding, comparing the pre- and post-implementation results shows improvement in the PSTs' ecoliteracy levels. As shown in Table 4, the median values of the PSTs increased from pre-instruction to post-instruction, with the post-instruction median reaching its maximum value. Using the Wilcoxon signed rank test, the computed p-value for the pre-instruction and post-instruction results is less than 0.001, which indicates that the null hypothesis is rejected. There is a significant difference between the PSTs' pre-instruction and post-instruction results of the ecoliteracy scale. Interestingly, the interquartile ranges (IQR) of the pre- and post-instruction results are equal (IQR=1.00). This means that the teaching packet produced a consistent increase in PSTs' ecoliteracy. Moreover, based on the computed Z-statistic, the effect size is also approaching the medium level, implying a moderately substantial change in the students' ecoliteracy levels. These results are equally significant as ecoliteracy is not limited to cognitive thinking but also permeates into attitudes and behavior for holistic learning and internalization.

Table 4. Wilcoxon signed rank test for ecoliteracy scale results (pre- vs. post-instruction)

Ecoliteracy scale results	Median	IQR	p-value	Z-statistic	Effect size (r)
Pre-instruction	4.00	1.00	<0.001	-2.977	0.48
Post-instruction	5.00	1.00			

Generally, the results suggest that the IB-STEAM teaching packet improved the conceptual understanding and ecoliteracy levels of the PSTs. This is highly consistent with studies that have documented positive results on utilizing IBL to foster ecoliteracy and similar educational goals at different academic levels [25]–[27], [39], [40], with some researchers combining it with other pedagogies [41], [42]. The results also support a prior study on STEAM education's effectiveness in higher education [43]. Existing literature also documented how IBL and STEAM education positively impacted the affective domain [44], [45]. As for the effect sizes, the findings are coherent with meta-analysis results that showed a high effect size for the 7E's learning cycle of IBL [46], while a previous study for STEAM education documented an average effect size [47]. Since IBL and STEAM education can separately produce positive effects, combining the two pedagogies is expected to improve student achievement or even have magnified impacts on student learning. Such is highly desired so PSTs become genuinely ecoliterate.

The results imply that interfacing the 7E's of IBL and STEAM education model in this study's instructional framework is seamless and effective. This is parallel to the integration done in previous studies for STEM, the forerunner of STEAM, into the 7E's of IBL, which produced positive effects [30], [48]. The 7E's of IBL fostered a constructivist form of learning. It builds upon their knowledge of the environment and enriches it through developmentally-sequenced and activity-based learning experiences. Such strengthened the various aspects of their learning. In addition, STEAM education heightened PSTs' participation throughout the 7E's learning cycle. By tapping into the five STEAM disciplines, PSTs were challenged to think creatively and apply 21st-century skills [28]. In the process, this helped them to develop and internalize ecoliteracy knowledge, values, and abilities. Accordingly, creativity and direct application contribute to the PSTs' capacity to become innovative problem-solvers in today's environmental crisis [49]. Thus, integrating IBL and STEAM education was highly influential in developing PSTs' ecoliteracy. However, more studies can elucidate the effects of this integration in higher education as lecture tends to be a dominant teaching methodology [50].

3.4. Perceptions of PSTs and teachers

Results of the APQ show that PSTs have an overall positive perception of the IB-STEAM teaching packet's learning experiences as shown in Table 5. The mean values for "interest/enjoyment" and "value/usefulness" are both above 5.00, while perceived choice is roughly equivalent to 5.00. The value/usefulness subscale has the highest mean, implying that PSTs manifested high self-regulation and internalized the significance of the IB-STEAM teaching packet's learning experiences [51]. The high mean value for interest/enjoyment reflects the PSTs' high intrinsic motivation in engaging with the teaching packet's learning experiences [51]. Comparatively, the perceived choice has the lowest mean/average among the three subscales, though its 4.98 mean value suggests that PSTs' level of autonomy is approaching a high level in terms of undertaking the learning experiences of the IB-STEAM teaching packet. This finding implies the need to foster a less controlling and more informational learning environment [52]. Furthermore, the low SD values for the three subscales (SD<0.5) also mean that the PSTs similarly perceive the interest, value, and perceived choice of their learning experiences.

Table 5. Summary of the results of the APQ

Subscale	Mean	SD
Interest/enjoyment	5.98	0.38
Value/usefulness	6.20	0.37
Perceived choice	4.98	0.41

To further support the results of the APQ, the perceptions of the PSTs and faculty members were also gathered through open-ended questions. The following are the main findings revealed using thematic analysis:

i) Preference to the progressive educational experiences. Both PSTs and faculty members liked the learner-centered set-up of the IB-STEAM teaching packet, with its fun, authentic, and engaging nature that promotes application, collaboration, creativity, critical thinking, and reflection. PSTs also positively viewed the content around which the learning experiences were organized as it is informative, interesting, meaningful, relevant, and significant to real-life context.
ii) Problematic and challenging aspects. PSTs and faculty members noted the major issue of time constraints in accomplishing the stages of the lesson, which limited the timely, efficient, and effective completion of the discussion, activities, and assessments. Faculty members also noted some lacking details in the teaching packet for instructional support, which weakened the quality of its delivery.
iii) Further enrichment of the teaching packet's learning experiences and instructional details. Both PSTs and faculty members suggested improving the time allocation of the lesson stages for feasibility. PSTs also preferred to augment the teaching packet's engagement by including more outdoor and hands-on activities, collaboration, opportunities for reflection, and cross-disciplinary connections. In addition, faculty members are more concerned with providing specific instructional support while affording flexibility like teaching tips for undertaking discussion, and implementing the activities.

Both APQ results and open-ended responses reveal positive perceptions toward the IB-STEAM teaching packet. The means of the "interest" and "value" subscales show that the teaching packet provided engaging learning experiences to the PSTs. Connectedly, this satisfies Capra's [6] proposition to provide authentic experiences when learning ecoliteracy for better engagement. Based on the self-determination theory (SDT), the packet's learning experiences fostered PSTs' intrinsic motivation in learning ecoliteracy [53], leading to statistically significant increases in conceptual understanding and ecoliteracy levels. Arguably, the 7E's of IBL can develop thinking skills, collaboration, and intrinsic motivation [54], while STEAM education fosters creativity and other important 21st-century skills [55]. In a nutshell, the results highlight how the teaching packet's experiences accounted for motivational and cognitive factors to ensure optimal learning. Furthermore, the heightened engagement of the PSTs nurtures their biophilia, the innate tendency to connect with nature.

While it is positively regarded, the IB-STEAM teaching packet has drawbacks. First, the comparatively lower mean for perceived choice is connected to the need for more instructional flexibility. Lack of time hinders the PSTs from accomplishing their activities effectively and puts them at risk of low-quality learning [56]. Previous studies have noted that the 7E's learning cycle of IBL and the STEM/STEAM education model needs significant class time [44], [47], [57]. Secondly, the teaching packet lacked some instructional details, which limits how it can be used effectively. Thorough familiarity and adequate instructional support are needed to properly implement the 7E's of IBL and the STEAM education model [44], [47]. Otherwise, the faculty member will not optimize his/her role as the MKO. All in all, these two weak points are entry points for further revisions and future studies. Since two pedagogies are used, utilizing IB-STEAM requires careful planning to ensure that concerns on feasibility and effectiveness of delivery are considered.

Despite the few drawbacks, the IB-STEAM teaching packet addressed the professional learning of PSTs in ecoliteracy as evidenced by the positive outcomes documented. While there are available materials for ecoliteracy, its uniqueness lies in the integrated pedagogies it adopted, which are proven effective. As ecoliteracy is a lifelong skill, the developed thinking, creativity, and motivation of PSTs can support the practice of ecologically-friendly behaviors. With the quality of learning provided by the packet, PSTs are expected to cultivate ecoliteracy among their future students once they become in-service teachers.

4. CONCLUSION

This study developed a teaching packet that incorporates the 7E's of IBL and STEAM education to augment the ecoliteracy of PSTs. It added to the existing studies on instructional materials development on ecoliteracy, featuring the pedagogy of IB-STEAM, for a healthy biosphere. Following the R&D design model, it was found that there was an opportunity to redesign the existing ecoliteracy material of the participating institution. The findings of the study unveiled the potential of the IB-STEAM teaching packet to foster the ecoliteracy of the PSTs, as evidenced by the preliminary evaluation results, increased pretest-posttest scores, increased ecoliteracy scale median values, and positive perceptions of PSTs and faculty members. Results also substantiate that the IB-STEAM teaching packet can still be improved to produce better gains in learning.

Based on the conclusions derived, recommendations for future research are raised. Due to a limited number of respondents, adding one or more implementation cycles is highly recommended to further test and improve the effectiveness of the IB-STEAM teaching packet. Ideally, PSTs from different teacher education programs are also involved in the upcoming implementation cycles. The utilization of IB-STEAM can be explored in other ecological topics, given its potential effectiveness. Future research can utilize it as an instructional framework in designing teaching-learning materials for higher education and even basic education, whenever appropriate.

This study provides significant implications for practice. Firstly, instructional materials development must consider using innovative and integrative pedagogies to promote optimal learning. Doing so helps higher education institutions become more attuned to modern education practices. However, testing these pedagogies needs careful planning. Secondly, successful ecoliteracy instruction requires doing away with traditional methods. Ecoliteracy instruction must promote active, interactive, and outdoor experiences for real-world exploration and creative problem-solving. As shown in this study, quality ecoliteracy instruction boosts the cognitive, motivational, and application-based creativity aspects of PSTs' learning.

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