



Pre-service biology teachers' motivational responses to the sustainable digital vegetation mapping program design: A pre-implementation study

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ABSTRACT

Plant awareness disparity (PAD) poses a challenge to botany education. However, students' evaluations of instructional designs before implementation remain underexplored. This study aimed to describe pre-service biology teachers' motivational responses to the Sustainable Digital Vegetation Mapping Program (SDVMP) and integrate these responses with their qualitative perceptions. A convergent mixed-methods design was employed involving 122 Biology Education students at Universitas Sriwijaya who had completed a Vascular Plant Botany course. Before completing the instruments, participants reviewed an infographic presenting the proposed SDVMP design. Quantitative data were collected using an adapted 34-item Instructional Materials Motivation Survey (IMMS) based on the four ARCS dimensions. Qualitative data were obtained through one open-ended question, and 109 responses were analysed thematically. The overall IMMS mean was 3.28 (SD = 0.36; $\alpha = 0.96$). Satisfaction ($M = 3.34$) and Relevance ($M = 3.34$) had nearly identical mean scores, followed by Attention ($M = 3.26$) and Confidence ($M = 3.19$). Eight themes emerged, with Appeal and Innovation (77.06%), Relevance and Usefulness (42.20%), and Program Clarity and Organization (33.94%) being the most prominent. Sustainability and Green Campus appeared in 20.18% of responses. Overall, students perceived the SDVMP design positively in motivational terms. However, these responses reflect preliminary evaluations of the infographic rather than evidence of program effectiveness or a reduction in PAD. The findings can inform formative refinement of the program design and provide a basis for evaluating its effectiveness after implementation.

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INTRODUCTION

Global biodiversity faces severe pressures from land-use change, overexploitation, and climate change. In this context, vascular plants function as primary producers and carbon sinks. They also provide the structural foundation of terrestrial ecosystems (Brondízio et al., 2019). However, plants often receive less attention than animals, a tendency widely discussed as plant blindness. Parsley (2020) proposed the term plant awareness disparity (PAD) to emphasize gaps in attention, appreciation, and awareness of plants, rather than merely individuals' inability to recognize species. This issue is relevant to biology education because attention to plants is an important component of biological literacy, ecological awareness, and understanding biodiversity (Stagg et al., 2025; Uno, 2009). It also warrants attention from pre-service biology teachers, as their experiences with and understanding of plants may influence how they introduce plant diversity to future students. However, implications for teaching practice should be considered a possibility requiring further investigation, rather than an established causal relationship.

Studies of PAD among pre-service teachers have consistently highlighted this concern, but they have used different approaches and generated different types of evidence. Bobo-Pinilla et al. (2024) identified tendencies to overlook plants using several types of measures. Telli (2025) demonstrated how this tendency manifests in field-based plant recognition, although the findings were limited to two participants. In Indonesia, Putra & Biologi Sel (2025) found an association between PAD and plant identification ability, while Soraya et al. (2026) showed that pre-service teachers mentioned animals more frequently than plants. In contrast to studies examining the occurrence of PAD or its associations with other variables, Fitriani et al. (2025) reported increases in indicators of plant awareness following a digital-based project.

Place-based botany education and digital technologies can be designed as complementary approaches to strengthen students' engagement with plants. Local vegetation can provide an authentic learning context in which students investigate not only plant morphology but also species characteristics, environmental adaptations, and relationships with ecosystems. Digital technologies can support this process without replacing direct observation of plants (Borsos et al., 2023; Corbacho-Cuello et al., 2025). During field activities, plant identification applications and mapping technologies can help students document morphological traits, identify species, and connect observational data with plant locations (Coşkunserçe, 2024; Kesler et al., 2024; Williams & Cederqvist, 2025). Integrating place-based learning, field observation, and digital mapping may therefore provide contextualized botany learning experiences that are also relevant to pre-service teachers' digital skills.

This study examines the Sustainable Digital Vegetation Mapping Program (SDVMP), designed for Biology Education students in a Vascular Plant Botany course. The program integrates five stages: strengthening conceptual understanding of plant morphology; conducting field observations and recording morphological data and coordinates; analyzing and categorizing vegetation; creating digital maps using Google My Maps; and presenting findings and developing sustainability recommendations. The sustainability analysis is designed to address environmental, social, and economic dimensions. The intended outputs are a digital map of campus vegetation and management recommendations. Through these stages, the SDVMP connects biological observation with geospatial technology and considerations of environmental, social, and economic sustainability. Before implementation, the proposed design warrants evaluation from students' perspectives. This evaluation can help identify motivational aspects and presentation features that may require refinement.

Pre-implementation evaluation can inform developers about students' initial motivational responses before resources are committed to program delivery. This study uses the ARCS framework (Attention, Relevance, Confidence, and Satisfaction), which underpins the Instructional Materials Motivation Survey (IMMS) (Keller, 2010). The IMMS was developed to assess motivational reactions to instructional materials. Loorbach et al. (2015) reported that the psychometric properties of the IMMS may depend on its context of use. Accordingly, results obtained using an Indonesian-language adaptation, with items contextualized for the SDVMP infographic, should be interpreted as a descriptive profile specific to this study. These results do not, by themselves, establish the construct validity of the adapted instrument.

Based on the literature reviewed, evidence remains limited regarding how pre-service biology teachers evaluate the motivational aspects of a place-based digital vegetation mapping program before implementation. The studies discussed have primarily examined the occurrence of PAD, its association with plant identification ability, field learning experiences, or changes in plant awareness following

program implementation. This study takes a different approach by examining students' motivational perceptions of an infographic presenting the proposed SDVMP before the co-curricular program is implemented. It does not test the program's effectiveness in increasing plant awareness, improving plant identification skills, or enhancing botany learning outcomes. Instead, it aims to provide preliminary insights into how prospective participants perceive the program design and how qualitative responses can complement the motivational profile obtained through the IMMS. The study addresses three research questions:

1. What is the motivational profile of pre-service biology teachers in response to the SDVMP design across the four ARCS dimensions?
2. How do students perceive the SDVMP design, as reflected in their open-ended responses?
3. How do the quantitative and qualitative findings complement each other in explaining students' motivational evaluations of the SDVMP design?

METHODS

Research Design

This study employed a convergent mixed-methods design. Quantitative and qualitative data were collected concurrently from the same respondents and analyzed separately. The two datasets were then integrated during interpretation using a joint display. This approach was selected to compare the structured motivational profile with perceptions emerging from open-ended responses (Cresswell & Plano Clark, 2018; Doyle et al., 2009). The analysis was descriptive and pre-implementation in nature. The design was not intended to test causal effects or program effectiveness.

Context and Program Description

The study was conducted among students in the Biology Education Study Program, Faculty of Teacher Training and Education, Universitas Sriwijaya. The campus environment was selected as the context for the SDVMP design because its vegetation has the potential to support place-based botany education. A previous study documented 114 seed plant species in the green areas surrounding the lecture buildings of the Faculty of Teacher Training and Education at Universitas Sriwijaya (Ermayanti et al., 2024). This figure provides a previously reported baseline for potential learning resources. It does not represent an inventory conducted as part of the present study.

The SDVMP was developed as a learning program comprising five planned stages: strengthening conceptual understanding; conducting field observations; analyzing and categorizing vegetation; creating digital maps using Google My Maps; and presenting findings and engaging in reflection. Three expert validators reviewed the program design. Their areas of expertise covered botany/plant biology, biology education and Education for Sustainable Development (ESD), and educational technology. According to the validation documents, the aggregate Aiken's V coefficient was reported as 0.956. The design was considered acceptable subject to minor revisions. These revisions were made before the infographic was presented to respondents. The Aiken's V value reflects the evaluation of the program design, not the validation of the IMMS instrument.

Participants and Respondent Characteristics

The participants comprised 122 active students enrolled in the Biology Education Study Program, Faculty of Teacher Training and Education, Universitas Sriwijaya. All respondents had completed a Vascular Plant Botany course. However, these two characteristics (active-student status and course completion) were not recorded as separate variables in the dataset. Age data were not collected. Therefore, respondent characteristics are reported using the available information, without estimating participants' ages. An overview of the respondents is presented in Table 1.

Respondents were selected because their academic backgrounds were relevant to the SDVMP content, particularly vascular plant morphology, plant observation, and vegetation identification. These experiences were expected to help them understand the program design infographic before providing their motivational evaluations. However, the respondent characteristics did not fully correspond to the program's target population: students currently taking the Vascular Plant Botany course. Respondent numbers were not analyzed separately, and the findings are interpreted as a description of the motivational responses of pre-service biology teachers with relevant academic experience. They should not be interpreted as a definitive estimate of the readiness of students currently taking the course.

Table 1

Respondent characteristics

Characteristic	Category	n	Respondents (%)	Total students in cohort
Gender	Female	100	82.00	0.00
	Male	22	18.00	0.00
Cohort	2022 (Semester 8)	40	32.08	94.00
	2023 (Semester 6)	82	67.02	95.00
Total		122	100.00	189.00

Note. Age data were not collected. All respondents had completed the Vascular Plant Botany course. The total number of students in each cohort represents the cohort enrolment, whereas the respondent percentages were calculated from the total study sample.

Materials Evaluation and Data Collection Procedures

The main data collection was conducted in May 2026. A Google Forms link was distributed to students through a WhatsApp group. The form contained the revised SDVMP infographic, updated in response to expert validators' feedback, along with the instruments to be completed by respondents. The object of evaluation was the program design infographic. It presented an overview of the program, its learning objectives, the five activity stages, the technologies to be used, the sustainability analysis covering environmental, social, and economic dimensions, and other design elements included in the material. Respondents were asked to review the infographic before completing the IMMS and submitting their open-ended responses. They did not conduct field observations or digital mapping as part of the data collection. The review period was neither standardized nor recorded. Consequently, the actual duration of exposure to the infographic is unknown for each respondent.

Quantitative and Qualitative Instruments

Quantitative data were collected using an Indonesian-language adaptation of the Instructional Materials Motivation Survey (IMMS), based on the ARCS model (Keller, 2010). The author independently translated the English-language instrument into Indonesian and then adapted the items for the evaluation of the SDVMP infographic. These adaptations ensured that the statements referred to the proposed program design rather than to experiences of participating in a program that had not yet been implemented. The translated version was not independently reviewed for language quality, nor was the instrument itself evaluated by experts. A pilot test involving 52 students was conducted using an initial 36-item instrument. After reverse-scoring negatively worded items, the initial instrument yielded a Cronbach's alpha coefficient of 0.94. Corrected item-total correlation analysis identified two items with coefficients below the predefined threshold of 0.20. These were Item 16 in the Confidence dimension ($r = 0.17$) and Item 24 in the Attention dimension ($r = 0.04$). Both items were therefore removed from the instrument.

The resulting final instrument comprised 34 items: 11 for Attention, 9 for Relevance, 8 for Confidence, and 6 for Satisfaction. In the pilot sample, Cronbach's alpha 0.94 for the final instrument. Responses were recorded on a four-point Likert scale, ranging from strongly disagree (1) to strongly agree (4). Seven negatively worded items were reverse-scored before analysis. For the main dataset, internal consistency was assessed using Cronbach's alpha for each dimension and the total score. This study did not conduct factor analysis, construct validation, or comprehensive psychometric validation of the translated and contextualized IMMS. Corrected item-total correlations and Cronbach's alpha coefficients were used to describe item characteristics and internal consistency. They were not treated as evidence that the construct structure of the adapted instrument had been validated. The IMMS scores were used to describe students' motivational responses to the program design infographic. Qualitative data were collected through one open-ended question that asked respondents to provide their general impressions after reading the program design. The question presented to respondents was: "Please share your general impressions after reading the developed Program Design." The question did not explicitly ask respondents to identify program challenges or barriers. Therefore, critical comments emerging from the responses were interpreted as spontaneous feedback within respondents' general perceptions, rather than as findings from an in-depth exploration of implementation challenges.

Data Analysis

Quantitative data were analyzed descriptively by calculating the mean and standard deviation for each dimension and item. Cronbach's alpha was also calculated for each dimension and the total score. Scores were interpreted using operational classification intervals established for this study: $M \geq 3.26$ for the very high category, 2.51–3.25 for the high category, 1.76–2.50 for the low category, and $M \leq 1.75$

for the very low category. These categories served descriptive purposes and were not treated as standardized IMMS norms. Corrected item-total correlations for the final instrument were also examined and are summarized in Appendix A. Open-ended responses were analyzed using inductive thematic analysis, following the phases of data familiarization, initial coding, theme development, theme review, theme definition, and report production (Braun & Clarke, 2006). Of the 122 responses, 109 were deemed meaningful for thematic coding. Themes were developed from the content of the responses. The codes and interpretations were then discussed with the doctoral supervisor through peer debriefing. Because a single response could contain more than one idea, the thematic categories were not mutually exclusive. Therefore, their percentages were not expected to sum to 100%. Integration was conducted by presenting the ARCS dimension results alongside the qualitative themes. The combined findings were then interpreted in terms of convergence, elaboration, qualification, and expansion of information.

RESULTS AND DISCUSSION

Quantitative Motivational Profile (RQ1)

Students' motivational responses to the SDVMP design were analyzed across the four ARCS dimensions (Attention, Relevance, Confidence, and Satisfaction). Table 2 presents the descriptive statistics, internal consistency, and score categories for each dimension and the overall IMMS score. At the item level, the statement "The content of this program will be useful to me" received the highest mean score ($M = 3.52$; $SD = 0.50$) and belonged to the Relevance dimension.

Table 2
Motivational profile and IMMS reliability by ARCS dimension

ARCS dimension	Number of items	M	SD	Cronbach's α	Category*
Attention	11	3.27	0.37	0.87	Very high
Relevance	9	3.34	0.38	0.89	Very high
Confidence	8	3.19	0.41	0.86	High
Satisfaction	6	3.34	0.40	0.87	Very high
Total IMMS	34	3.28	0.36	0.96	Very high

Note. Categories are based on the operational intervals established for this study ($M \geq 3.26$ = very high; 2.51–3.25 = high; 1.76–2.50 = low; $M \leq 1.75$ = very low). These intervals are not standardized IMMS norms. Cronbach's alpha indicates the internal consistency of responses in this sample and does not establish the construct validity of the adapted instrument.

The profile indicates that students evaluated the SDVMP design positively at this preliminary stage, particularly in terms of its perceived usefulness. However, these findings must be distinguished from evidence of actual botany learning. Respondents reviewed only the infographic before the program was implemented. Therefore, the ARCS scores reflect their responses to the program as presented and the learning experiences they anticipated. High scores do not indicate that students have improved their plant identification skills, developed biodiversity literacy, or maintained their motivation while undertaking field activities.

The interpretation of high scores also requires consideration of alternative explanations related to the measurement conditions. Because respondents had only reviewed the infographic and had not experienced the program, their initial evaluations may have been influenced by the novelty of the digital presentation. Research on mobile learning has shown that perceived novelty can be associated with motivation, suggesting that novelty should be distinguished from sustained instructional benefits (Jeno et al., 2019). In addition, because the data were self-reported, some responses may have been influenced by social desirability bias, a recognized source of bias in survey research (Nederhof, 1985). A tendency to agree with statements or to adopt response strategies requiring less cognitive effort may also be relevant when interpreting survey responses (Krosnick, 1991).

In this study, the duration of infographic review was neither standardized nor recorded. These potential influences were not measured directly. Consequently, they cannot be identified as causes of the high scores. Instead, they should be considered when interpreting the findings. The scores are best understood as perceived motivational responses to the infographic before implementation, rather than as measures of actual motivation during program delivery.

The distinction between evaluations of a program design and actual learning outcomes becomes clearer when this study is compared with research evaluating implemented botany programs. Corbacho-Cuello et al. (2025) evaluated a botanical inquiry trail involving pre-service teachers by

measuring emotional experiences, interest in plants, and botanical knowledge in the context of field activities. Fitriani et al. (2025) also evaluated a digital plant project after students had participated in the activities, focusing on indicators of plant awareness. Both approaches provide evidence about experiences or outcomes following an intervention. In contrast, the present SDVMP study collected evaluations when students had only reviewed the infographic. This difference in research stage and type of evidence limits the conclusions that can be drawn. The findings provide formative information about the initial reception of the design, but they do not establish that the SDVMP will improve botanical knowledge, plant identification skills, or plant awareness.

Confidence had the lowest mean among the four dimensions, although it remained within the high category according to the operational intervals used in this study. This pattern is insufficient to conclude that students lacked confidence or had already experienced difficulties with plant identification. Conceptually, plant identification requires students to observe and compare morphological characteristics, interpret taxonomic information, and verify species identities. Therefore, responses to the infographic should be used to identify aspects of the design that may require more explicit instruction and support. They should not replace direct assessments of identification performance. Confidence, identification accuracy, and data quality need to be assessed directly when the program is implemented.

The motivational profile can serve as formative feedback for refining the design before implementation. Positive responses to the program's appeal and perceived usefulness should inform a design that is not only engaging but also helps students understand the learning demands and expected outcomes. During implementation, subsequent evaluation should examine whether the instructional design supports students in conducting investigations aligned with the learning objectives. It should also determine whether their actual learning experiences correspond to their initial evaluations of the infographic.

Students' Perceptions of the SDVMP Design (RQ2)

Table 3 presents the themes synthesized from respondents' answers, illustrative statements, and descriptive frequencies of students' perceptions of the SDVMP design. The thematic patterns reveal two distinct levels of response. Appeal and innovation were the most frequently mentioned general impressions. Relevance and Usefulness, Clarity and Systematic Structure, and Digital Technology Integration reflected more specific aspects of the program design. These findings indicate that students not only expressed positive impressions but also commented on the program's usefulness and planned learning components. However, theme frequencies reflect the aspects respondents chose to mention. They do not measure motivational intensity, indicate the prevalence of learning difficulties, or demonstrate that respondents had mastered the skills associated with these themes.

Table 3
Themes of Students' Perceptions of the PDVB Programme Design (n = 109).

Theme	Example Statements	f	%
T1: Appeal & Innovation	"...very good and engaging." (MR) "...captures attention and enthusiasm..." (DF) "...sparks curiosity and motivates..." (NA)	84	77.06
T2: Digital Technology Integration	"...learning digital mapping technology via mobile phone..." (SR) "...trains technology, observation, and analytical skills..." (ASS) "...spatial digital literacy... strengthens the campus database." (MAI)	35	32.11
T3: Contextual Field Learning	"...hands-on observation and mapping practice in the field." (OL) "...a direct hands-on learning experience in the field..." (ASS) "...exploring the surrounding environment... developing observation skills." (APB)	32	29.35
T4: Relevance & Utility	"...will be very helpful for students." (IN) "...makes learning easier for students." (LP) "...offers many benefits and broad understanding..." (DS)	46	42.20
T5: Sustainability & Green Campus	"...realising a green campus and sustainable campus vegetation management." (Anon)	22	20.18

Theme	Example Statements	f	%
	"...we learn what vegetation grows on campus." (MRS) "...increases awareness of the campus environment." (APB)		
T6: Clarity & Systematic Structure	"...clear and helps students understand the flow and objectives." (SWK) "...immediately understand the instructions... easy to apply." (SA) "...the information conveyed is clear and easy to understand." (CP)	37	33.94
T7: Skill Development	"...trains technology, observation, analytical, and teamwork skills." (ASS) "...develops observation and analytical skills..." (APB) "...sharpens sustainability analysis and digital literacy skills; suitable for HOTS." (LIA)	19	17.43
T8: Suggestions & Critical Notes	"...too complex and sequential, making it difficult to follow." (AW) "...needs consistency: percentages or fractions?" (AMM) "...the content is too dense and difficult to read." (DC)	6	5.51

Positive perceptions of digital technology and field-based learning should be considered alongside evidence concerning attention to plants and learning processes in the field. Bobo-Pinilla et al. (2024) used recognition, identification, memory, and attention tasks. Their findings revealed lower levels of plant recognition and recall than animal recognition and recall among pre-service teachers. In contrast, Williams & Cederqvist (2025) examined the use of the Seek application alongside field guides. They found that the application could help students attend to biodiversity, compare characteristics, and investigate species. However, identification limitations still required taxonomic knowledge and instructor support. Kesler et al. (2024) showed that visual observation tasks, peer exchange of findings, and immediate educator feedback provide important support for outdoor science learning.

These studies examined actual abilities or learning experiences, whereas respondents in the SDVMP study evaluated only an infographic. Moreover, Google My Maps is designed primarily for spatial mapping rather than automated species identification. Taken together, these findings indicate that initial acceptance of technology should not be equated with a reduction in plant awareness disparity or improved identification accuracy. Technology should be incorporated into guided investigations that include direct observation, taxonomic verification, and clear feedback.

In the SDVMP design, this principle can be translated into an explicit sequence of tasks. At each observation point, students should first record several diagnostic plant characteristics and habitat conditions. They should then use digital devices to document their observations and record coordinates and locations on a map. Plant identities should subsequently be verified using an identification key, a field guide, or a reliable taxonomic source. Uncertain identifications should be flagged and discussed rather than immediately accepted as correct. After verification, students should enter the data into the map and explain the relationships among morphological characteristics, locations, and interpretations of vegetation distribution. This sequence clarifies the function of each tool and ensures that mapping activities remain grounded in biological evidence rather than focusing solely on operating digital devices.

Concerns that digital devices may distract students from plants should be considered cautiously. This study did not measure screen time, observational behaviour, or the extent of students' sensory engagement with plants. Therefore, it cannot establish that technology reduced students' direct attention to plants. Nevertheless, the design could help mitigate this potential risk by requiring students to observe plants before using digital devices. Screen use should be limited to relevant functions, such as documentation and location recording. Students should then return to direct specimen examination whenever identification results remain uncertain. These recommendations need to be evaluated through observations of the learning process when the SDVMP is implemented.

Outdoor learning does not automatically become meaningful investigation simply because activities are moved from the classroom to the campus environment. To support inquiry, each SDVMP stage should provide scaffolding that helps students answer three questions: What should they observe? What evidence should they record? How should they use that evidence to identify plants and interpret vegetation distribution? Step-by-step instructions, examples of expected field notes and maps, and feedback during the verification stage can help connect field activities with learning objectives. The need

for structured visual tasks and educator feedback is also consistent with Kesler et al. (2024), who highlighted the importance of supporting pre-service teachers during outdoor science learning.

The Sustainability and Green Campus theme appeared in 22 responses (20.18%). Its occurrence indicates that some respondents recognized the sustainability orientation explicitly presented in the SDVMP infographic. However, it does not demonstrate that they had developed sustainability competencies. Distinguishing between recognizing a program's objectives and developing the ability to interpret sustainability issues is important in teacher education informed by Education for Sustainable Development (ESD). Jegstad et al. (2018) emphasized the importance of connecting field experiences with inquiry and reflection in sustainability education for pre-service science teachers. In the SDVMP context, sustainability should be incorporated into activities in which students interpret vegetation data and develop evidence-based recommendations. It should not be presented solely as a program objective. The development of these competencies still needs to be assessed after implementation.

The Suggestions and Critical Comments theme appeared in six responses (5.50%). This low frequency is insufficient to conclude that design problems affected only a small proportion of students. The open-ended question asked respondents to provide general impressions and did not explicitly invite them to identify challenges. Nevertheless, comments concerning information density, the complexity of the sequence, and readability provide useful feedback for refining the design. These comments support the need to simplify the presentation, clarify the relationships among stages, and provide examples of expected mapping outputs. The findings are therefore more appropriately used as design feedback than as an estimate of the prevalence of student difficulties.

Integration of Quantitative and Qualitative Findings (RQ3)

Quantitative and qualitative data were integrated to identify aspects of the SDVMP design that received positive responses and those requiring further refinement. The mean scores for Relevance and Satisfaction were nearly identical, whereas Attention and Confidence had descriptively lower means. Table 4 summarizes the interpretive relationships between the four ARCS dimensions and the open-ended response themes. It does not treat scores and theme frequencies as equivalent measures.

Table 4

Joint Display Triangulation between ARCS Dimensions and Qualitative Themes

Findings	Qualitative findings	Integration pattern	Integrated interpretation
Relevance: M = 3.34; SD = 0.38; very high	Relevance and Usefulness (42.20%)	Convergence	Both data sources indicate that perceived usefulness was important to respondents. This reflects anticipated benefits rather than demonstrated learning outcomes.
Attention: M = 3.27; SD = 0.37; very high	Appeal and Innovation (77.06%); Digital Technology Integration (32.11%)	Elaboration	The themes contextualize students' initial impressions of the design's appeal and digital elements. Theme frequencies are not direct measures of Attention.
Satisfaction: M = 3.34; SD = 0.40; very high	Appeal and Innovation (77.06%)	Elaboration	Positive comments help contextualize students' impressions of the design. However, they do not demonstrate that appeal caused higher Satisfaction. The means for Relevance and Satisfaction were nearly identical, differing by approximately 0.002.
Confidence: M = 3.19; SD = 0.42; high	Clarity and Systematic Structure (33.94%); Suggestions and Critical Comments (5.50%)	Qualification	Comments about information density and complexity provide design feedback. They do not indicate the prevalence of learning difficulties or low confidence.
Not measured through ARCS	Sustainability and Green Campus (20.18%)	Expansion	Some respondents recognized the sustainability orientation presented in the program. These responses do not demonstrate increased ecological awareness or the development of ESD competencies.

The convergence between the Relevance score and the Relevance and Usefulness theme indicates that perceived usefulness was prominent in students' initial evaluations. The item concerning the program's usefulness also received the highest item-level mean and was assigned to the Relevance dimension in the final item mapping. Nevertheless, this relationship represents interpretive alignment. It does not establish that both data sources measured identical constructs or that students had actually experienced the anticipated benefits after program implementation. The Appeal and Innovation theme provides context for students' initial impressions of the program presentation. It can be interpreted alongside the Attention and Satisfaction dimensions. However, theme frequency does not measure the intensity of either dimension. The open-ended question also did not explicitly ask respondents to explain their motivational scores. Therefore, the theme helps clarify how students described the infographic, but it does not demonstrate that appeal or innovation caused the Attention or Satisfaction scores.

The integrated findings of this study direct attention toward the implementation stage, particularly the evaluation of the SDVMP in terms of alignment between the objectives presented in the program design, the learning experiences that actually occur, and the quality of the outputs produced by students. This evaluation could examine the implementation of each program stage, the completeness and accuracy of vegetation data, and the extent to which the mapped evidence supports the sustainability recommendations developed by students. Initial motivational responses could serve as one source of information for program evaluation. However, they should be complemented by evidence from the learning process and its resulting products. These evaluation components remain proposed areas for further investigation because the present study was conducted before the SDVMP was implemented.

Study Limitations and Directions for Future Research

This study has several limitations. First, it was conducted at a single university, and respondents evaluated only an infographic before the program was implemented. Therefore, the findings cannot be directly generalized to other contexts or interpreted as evidence of SDVMP effectiveness. Second, respondents had completed the Vascular Plant Botany course, whereas the program was designed for students currently taking the course. Consequently, the responses of the actual target population have not yet been assessed directly. Third, age data were not collected, and the duration of infographic review was neither standardized nor recorded. Fourth, the IMMS was translated and contextualized by the author without independent language review or specific expert evaluation of the instrument. It also did not undergo construct validation or factor analysis. Internal consistency alone does not establish the construct validity of the adapted instrument. Fifth, the qualitative data were obtained from a single open-ended question about general impressions. The question did not explicitly address challenges. Therefore, the critical comments cannot be considered a comprehensive assessment of implementation barriers. Sixth, learning effectiveness, changes in PAD, species identification ability, biodiversity literacy, and pro-environmental behaviour were not measured. Finally, novelty effects, social desirability bias, and acquiescence tendencies were not measured directly. These possibilities should be considered alternative explanations rather than established causes of the high scores.

Future observations of the learning process should also document how students divide their attention between plants and digital devices, when they use screens, and how they verify identification results. Qualitative data could be collected through several questions that explicitly explore perceived benefits, difficulties, and support needs during the activities. This approach could help examine whether initial motivational responses are associated with actual engagement and learning outcomes. It could also identify aspects of the design that need to be adjusted in response to students' experiences.

CONCLUSION

This study shows that pre-service biology teachers reported generally positive initial motivational responses to the SDVMP design, particularly regarding its perceived usefulness, appeal, and innovation. Integrating quantitative and qualitative data provided formative insights into positively perceived design features and areas requiring improvement. These included clarifying instructions, reducing information density, and organizing activities into a more systematic sequence. The findings provide a basis for refining the design before implementation. They do not demonstrate that the SDVMP has improved plant awareness, identification skills, or botany learning outcomes.

Future implementation should integrate direct observation of plant morphology with purposeful use of digital technology, taxonomic verification of plant identities, and guidance and

feedback at each stage. Further research should evaluate SDVMP effectiveness using a pretest–posttest design with a comparison group. This evaluation should include measurements of plant awareness disparity before and after the program, direct assessments of observation and identification skills, and evaluations of the quality of vegetation data mapped by students. This approach is needed to determine whether initial motivational acceptance is associated with changes in learning outcomes after program implementation.

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Appendix A. Item-Level Statistics for the Final IMMS Instrument

Table A1 presents the mean and standard deviation for each item after reverse-scoring negatively worded items, together with the corrected item–total correlation. The numbering follows the sequence of the 34 items in the final instrument used for the main data collection (N = 122). These data are provided for descriptive transparency; the table does not constitute a test of construct validity.

Table A1. Descriptive statistics and corrected item–total correlations for individual items

No.	Dimension	Brief item description	M	SD	Corrected item–total correlation
1	Confidence	Ease of following the program	3.30	0.53	0.67
2	Attention	Initial appeal of the program	3.33	0.49	0.60
3	Attention	The program is boring [R]	3.32	0.55	0.54
4	Relevance	Relevance to learning interests	3.22	0.52	0.54
5	Attention	Presentation helps maintain focus	3.33	0.51	0.68
6	Confidence	Confidence after reviewing the general overview	3.32	0.52	0.67
7	Attention	Elements stimulate curiosity	3.40	0.53	0.71
8	Attention	Repetition of material causes boredom [R]	3.07	0.65	0.43
9	Attention	Surprising or unexpected elements	3.10	0.51	0.37
10	Attention	Presentation quality sustains attention	3.27	0.55	0.65
11	Attention	The program is too abstract [R]	3.11	0.69	0.49
12	Satisfaction	Confidence in mastering the material while reviewing it	3.25	0.57	0.67
13	Relevance	Connection with prior knowledge	3.25	0.49	0.70
14	Relevance	Usefulness of the program content	3.52	0.50	0.68
15	Confidence	Difficulty understanding most of the material [R]	2.95	0.70	0.47
16	Relevance	Value of knowing the content and structure	3.41	0.51	0.70
17	Relevance	Alignment with learning needs	3.33	0.54	0.67
18	Relevance	Examples of application in real-life contexts	3.30	0.53	0.65
19	Relevance	Applicability to professional practice	3.35	0.51	0.72
20	Relevance	Clarity of program objectives	3.39	0.51	0.70
21	Confidence	Confidence in mastering the material being taught	3.33	0.51	0.72
22	Confidence	Organization of the material supports confidence	3.31	0.52	0.75
23	Confidence	Difficulty understanding most of the content [R]	3.07	0.67	0.57
24	Confidence	Confidence in demonstrating mastery	3.27	0.53	0.78
25	Satisfaction	Feedback on progress in understanding	3.37	0.48	0.78
26	Satisfaction	Enthusiasm despite imperfect results	3.33	0.55	0.55
27	Confidence	The content is too complex [R]	3.04	0.66	0.49
28	Attention	Understanding develops during review	3.30	0.49	0.77

No.	Dimension	Brief item description	M	SD	Corrected item-total correlation
29	Satisfaction	Satisfaction with activity achievement	3.35	0.48	0.72
30	Attention	The program is unenjoyable or not useful [R]	3.31	0.67	0.65
31	Attention	An engaging approach increases enjoyment	3.38	0.52	0.72
32	Relevance	Feedback explains whether responses are correct or incorrect	3.32	0.53	0.65
33	Satisfaction	Enjoyment and desire to learn more	3.36	0.52	0.74
34	Satisfaction	Program quality is commensurate with the effort required	3.40	0.49	0.68

Note. [R] indicates a negatively worded item that was reverse-scored before calculation. The numbering follows the final instrument after two items were removed from the pilot version. Values are rounded to three decimal places.