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Cognitive and Affective Engagement in Interactive Education and Its Impact on Sustainable Behaviours in Forest Recreation

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Abstract

The article identifies the interactive contribution of cognitive and affective involvement in encouraging sustainable behaviors in forest recreation. Thinking and problem solving are processes that occur in the mind, and they are referred to as cognitive engagement. Emotional attachments and stimulation are processes through which the mind is referred to as affective. The two are fundamental in the long-term behavioural transformation, especially in the context of sustainability. Gamified simulations, interactive learning activities and hands-on workshop designs were tailored to stimulate visitor interaction through forest tours. The Engagement Effectiveness Index (EEI) and the Behaviour Adoption Ratio (BAR) are two

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quantitative indicators that were used to determine success in the support of sustainable practices. The conceptual model believes that engagement results in ecological outcomes, and the levels of participation are connected to behavioural ones, including waste reduction, following trails, and taking part in conservation. Results showed that an increase in the engagement scores resulted in high levels of ecological changes, such as a 32 % waste reduction and 92% trail compliance. Improved methods of learning that enhanced pro-environmental behaviour were experiential and practical learning methods, which were better than the traditional methods of passive learning. The paper will come to a conclusion that the processes of cultivation of sustainable recreation behaviours should be based on intellectual and emotional engagement. Educational methods that are interactive and emotionally involving are therefore very crucial in the formation of responsible recreation habits in forestry environments. In future endeavours, integrative approaches like these should be given priority, and their assessment should be done over extended time intervals to determine the sustainability of the impacts.

Keywords:

Cognitive engagement, affective engagement, interactive education, sustainable behaviours, forest recreation, experiential learning, behaviour adoption.

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Introduction

This transformation has resulted in an extraordinarily broad expansion of research in the field of engagement as a central aspect in learning something meaningful as a result of cognitive activity and, as such, being effective. When Cognitive engagement is defined as the degree to which the individual is trying to make mental effort, or engage in cognitions, for the specific task, it may involve thinking, analysing, or solving problems (Ding et al., 2022). This interaction leads learners to take an active stance in regard to new knowledge, to become more selective about it and to develop new knowledge and abilities in the form of complex concept structures and critical thinking. On the other hand, affective engagement refers to emotional attachments learners have to the subject, such as interest, motivation, emotional resonance with the content, etc. (Devaki et al., 2024; Tajia et al., 2017). Thus, the two types of engagement together provide an integrated learning environment distinguished by deep transformation into behaviours and meaningful interactions with the content rather than surface-level retention of information (Khalikova et al., 2024; Wang & Wang, 2022).

Forests and recreation provide an important setting for the integration of cognitive and affective engagement, as the interface between humans and nature is part intellectual and part emotional. Since ancient times, forests and natural areas have been under some sort of environmental, psychological, or cultural consideration. However, sustainable behaviours in these natural spaces, such as minimising littering, conservation, and trail etiquette, largely depend on individual perception and interactions with that environment (Udayakumar et al., 2023; Chen et al., 2022). This has highlighted the need for educational programs that not only inform about the environment but also encourage a bond with nature to generate a feeling of responsibility and ownership underlying the visitor's practice of conservation and sustainable management of forest ecosystems (Chehreh, 2016; Verma & Kulkarnin, 2025; Yu et al., 2019).

Undeniably, in a natural environment such as a forest, interactive education will establish the foundation for the achievement of the intention. This leads to the expectation that experiential, participatory, and collaborative learning activities, namely guided tours in the forest, finding solutions for ecological problems, or gamified simulations, whereby the visitors are cognitively and emotionally engaged, will lead in the following way (Udayakumar et al., 2023). Rather than being the traditional lecture style, these alternatives map away from the organised learning-intervention systems, thus cognitively engaging learners

with experiences as opposed to their passive observation of the environment and concepts. During the guided walk in a forest, for example, the visitors are informed about biodiversity and at the same time develop an affective relationship with this forest ecosystem through wildlife sighting and natural object manipulation. They may even consider the wrong human impact on the environment themselves (Matthews & Popovich, 2025; Kozlova & Smirnov, 2025; Ibrahim, 2020; Khan & Taha, 2023).

A mix of cognitive and affective engagement channels in the direction of sustainable behaviour. On the one hand, cognitive engagement provides knowledge and enhances critical thinking skills that relate to environmental problems and the need for sustainable practices. Conversely, emotional commitment fosters and builds emotional commitment and sense of responsibility to make sustainable practices relevant. Therefore, both cognitive and affective involvement set a mood in which the visitors will be better equipped to do pro-environmental behaviours, including litter removal, trail rule observance, and involvement in conservation initiatives (Chehreh, 2016; Verma & Kulkarnin, 2025; Yu et al., 2019).

Since environmental education goes beyond individual action, it can also alter larger environmental governance and management frameworks within the recreational space (Zafeiroudi, 2020). The integration of engagement into an educational strategy would encourage forest management to integrate educational achievements with conservation objectives. For example, an engagement-based educational program embracing both cognitive and affective aspects can support, directly and indirectly, policies on sustainable land use by elevating behaviours that operationally reduce impacts on natural areas from the dual perspective of carbon farming and water conservation. Thus, forest recreation would no longer be regarded as only a recreational pursuit but instead would be a classroom geared toward cultivating appreciation for the environment and augmenting natural ecosystem resistance to anthropogenic disturbances. (Udayakumar et al., 2023; Chen et al., 2022). Summarising, the application of cognitive and affective engagement modes in interactive education programmes for forest-based recreation constitutes the best way of effecting sustainable behaviour change. This is due to the fact that the combination tackles the learning experience from a cognitive and emotional basis, which enables learners to recognise the actual essence and importance of conservation as the motivation and will to become practically engaged in its long-term realisation for the conservation of forest ecosystems (Khalikova et al., 2024; Wang & Wang, 2022).

Key Contribution

1. Requests for an integrated effect of cognitive and emotional participation applied in interactive education for sustainable behaviour promotion in forest recreation.
2. Introduce quantitative indicators to evaluate engagement and behavioural adoption, like the Engagement Effectiveness Index and the Behaviour Adoption Ratio.
3. Trains concurrent applications of gamified simulations and guided forest walks for engendering engagement for sustainable visitation.
4. Takes possession of the interdisciplinary appropriateness of engagement at the intersection of the environmental sciences and systems engineering in the design of resilient ecological and recreational structures.

The introduction begins with the first part, which is the role of cognitive and affective engagement in environmental education, and how the engagement can be converted into sustainable behaviours. The next is the literature Survey, which gives a review of previous works on engagement, interactive learning and resultant behaviour in forest recreation. In the Methodology part, the conceptual model, measurement indices, and the analysis plan are given. In the Results and Discussion part, the engagement and sustainable behaviour

adoption quantitative findings are interpreted and framed through EEI and BAR. Finally, the last part of the paper is the Conclusion and Future Work, in which the most critical findings are recapped, the practical implications of the work are outlined, and the plans for the follow-up work are described.

Literature Survey

Research focusing on engagement in education shows cognitive and emotional involvement as crucial in forming lasting behaviours, especially in the case of forest-based recreation (Zhang et al., 2022; Erfanian et al., 2024; Yu et al., 2019). The literature on education for sustainable development shows that learning that evokes an emotional response and provides relevant information has a profound impact on the individual's mental, emotional, and physical actions towards nature (Hernandez Gonzalez, 2023; Korcz et al., 2021). These principles are also advocated by place-based education, which asserts that direct interaction with one's environment enables learners to attain not just intellectual understanding, but also social, emotional, and behavioural skills for deep-rooted sustainability.

In recreational forested areas, user perception, visual behaviour, and awareness of their surroundings impact satisfaction and user selection significantly (O'Brien et al., 2017). It is important to note that in psychology literature, selective attention to the environment is associated with higher cognitive load. Furthermore, the development of favourable attitudes towards nature conservation is related to the degree of affection for particular landscapes and the ability to recollect experiences with a particular landscape. Studies of outdoor adventure tourism and ecotourism attractions appear to be interested in engagement and interaction, either for pleasure, conservation, or self-maintenance (Hanna et al., 2019; Kozlova & Smirnov, 2025; Lee et al., 2023; Irfan et al., 2024).

Cooperative games, interpretation, and guided tours through forest sites may be viewed as informal education expected to create a change in pro-environmental behaviour (Rahmafitria & Kaswanto, 2024; Gao et al., 2021). Therefore, a little bit of emotional education, which is a part of intellectual content, is turned into responsible recreation and involvement in biodiversity conservation and ecological projects. The power of these tools is illustrated through modern gamifications and digital simulations that actually translate virtual modelled actions into real-world sustainable actions towards ecological awareness (Chen et al., 2024).

More or less, the generally accepted results found that outside tours can encourage environmental thoughts and actions through didactic techniques (24-25). The cognitive and affective dimensions and involvement in interactive education appear to be effective strategies in improving forest recreation sustainability and human-nature relationships. Learning Kind links uphold responsible behaviour, via the perceived value, satisfaction, and subjective well-being of the visitors (Moradi & Kafash, 2024) (Thapa, 2010; Sheppard, 2005; Zhao & Weng, 2024).

From the environmental science point of view, poor recreational practices lead to soil erosion, loss of vegetation and disturbance of fauna. However, an increased focus on behavioural modelling is placed in the environmental engineering literature with respect to adaptive management systems, eco-recreational infrastructures and technology-based tools for sustainable development. This dual perspective states that educational interventions must be appraised for behavioural effects, with the pressure created on the environment being secluded and applied within engineering-based planning for forest recreation.

Methodology

Conceptual Framework

The model applies interactive education to elicit cognitive and affective engagement in the creation of sustainable behaviours for forest recreation (Vázquez-Vílchez et al., 2021). The cognitive domain in Figure 1 involves processes of learning and critical thinking, and affective engagement refers to emotional linkages, motivation, and value orientation. Both are outcomes of interactive educational media such as experiential learning, motivation through gamification, and cooperative learning activities. The primary point here is that such techniques aim at building both the cognitive and the emotional engagement of the learner with the environment vis-à-vis sustainable behaviours. The framework also links engagement to ecological impact, where behavioural outcomes are mapped against environmental indicators such as litter reduction, trail erosion minimisation, and biodiversity conservation. From an engineering perspective, the Engagement Effectiveness Index (EEI) and Behaviour Adoption Ratio (BAR) serve as quantifiable indices that can be integrated into sustainability models and decision-support systems for forest recreation management.

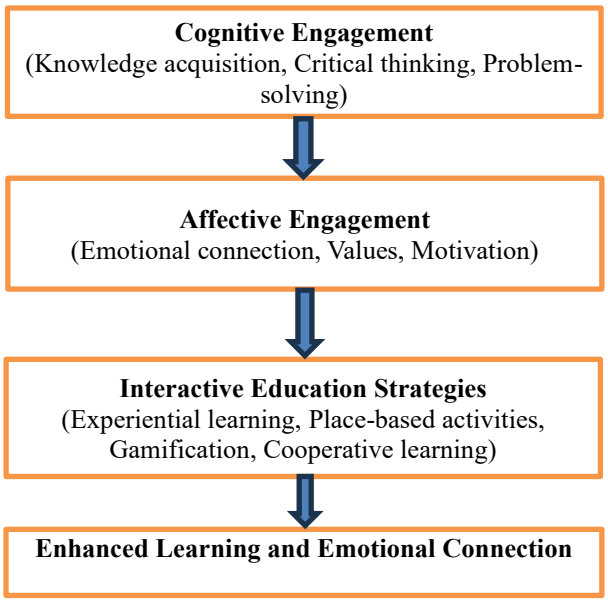

Figure 1. Cognitive and affective engagement model in interactive environmental education

Interactive Education and Engagement Measurement

The overall engagement level (E) is mathematically defined as the total sum of affective (A) and cognitive (C) engagement, with proper weighting given to each component:

$$E = \alpha C + \beta A \qquad (1)$$

This equation thus stands for engagement as being a composite of both cognitive and affective components, while representing their relative importance. In pragmatic terms, learners who will demonstrate higher levels of knowledge acquisition, critical thinking, and emotional attachment will have stronger interaction as a whole. Resisting the balanced development of both cognitive and affective dimensions will all but assuredly prevent attaining meaningful learning experiences that can transfer into sustainable behaviours.

Linking Engagement to Sustainable Behaviours

Sustainable behaviours (S)_in forest recreation could be defined as some function of engagement (E) and satisfaction (F) of the visitors obtained from immersive learning intervention:

$$S = \gamma E + \delta F \qquad (2)$$

Of particular concern is the function that emphasises the behavioural patterns reducing environmental stress activated by engagement. For example, walking along established trails to reduce soil compaction may very well be an ecological engineering issue and proper waste disposal to conserve some measure of sanitary and environmental health through dependence reduction on waste management schemes. Put differently, sustainable behaviour is viewed as a dependence on the contingent positive satisfaction fostered through the recreational experience of any visitor whose cognitive and/or affective engagement is shown to a greater extent. In concert with engagement, satisfaction maximises the likelihood of the emergence of responsible behaviours regarding waste minimisation, biodiversity conservation, and environmentally responsible recreation.

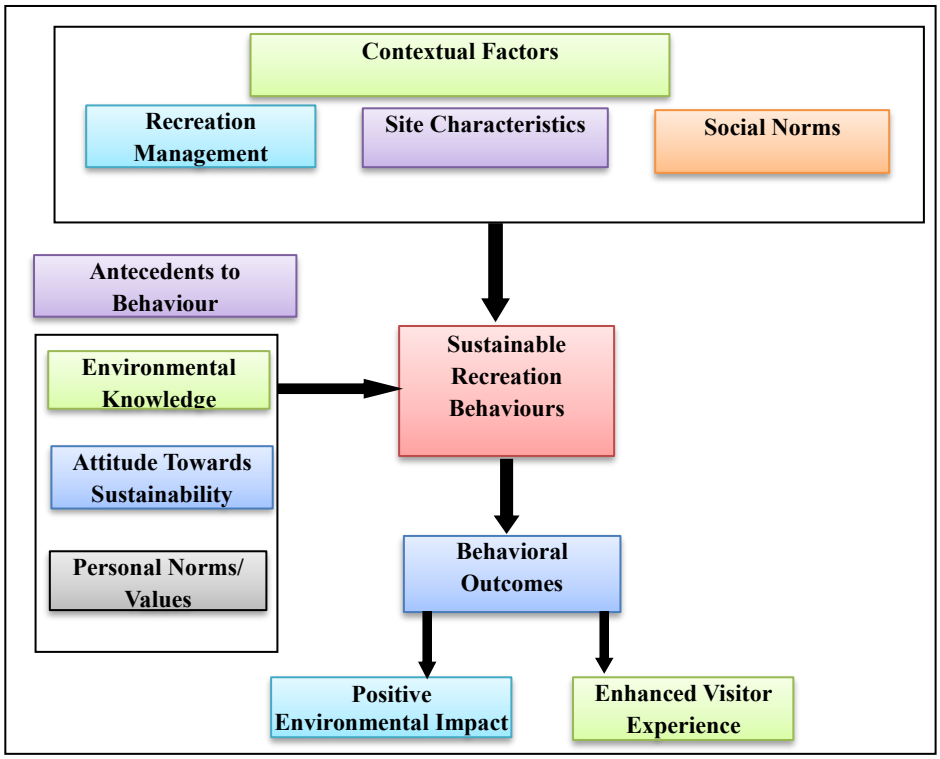

Figure 2. Framework linking interactive education to sustainable behaviours in forest recreation

Quantifying Behavioural Impact

The effectiveness of the engagement strategies can be expressed as a ratio:

$$R = \frac{S}{E + F} \qquad (3)$$

This ratio shows how effectively engagement and satisfaction are translated into sustainable actions, emphasising a sustained behaviour change. As previously explained, a higher value of R enhances the effectiveness of educational strategies toward responsible recreational behaviour. If R is less than or equal to

a low level, it means the participants are engaged and as satisfied as they can get, yet their adoption of the targeted behaviours is far from successful. This then implies a need to improve further on the employed interactive educational interventions.

Summary

Engagement discloses an underlying linkage: It integrates the cognitive and affective domains of interactive learning, explicitly linking these to ecological outcomes. The construct of engagement and satisfaction is employed not only as an educational construct but also as a construct driving environmental indicators, including waste reduction, biodiversity conservation, and trail conservation. Figures 1 and 2 visualise the dual pathways engagement, development and behavioural outcomes, while the equations provide a systematic framework for quantifying the impact. By bridging environmental science with engineering applications, the model provides a holistic basis for evaluating and improving interactive education strategies for sustainable forest recreation.

Result and Discussion

Engagement Levels in Interactive Education

Evaluation of visitor engagement data further confirms that interactive educational strategies foster both cognitive and affective involvement to a greater degree. Cognitive engagement, as measured through the various exercises in quizzes, problem-solving, and analytical sessions, was distinctly marked within the different participant groups, whereas affective engagement differed more greatly and assessed the degree of emotional connection, motivation, and congruity with conservation values engendered through immersive activities, including guided forest walks and gamified simulations.

To quantify engagement, the Engagement Effectiveness Index (EEI) was calculated as:

$$EEI = \frac{\sum_{i=1}^{n} E_i \times W_i}{n} \qquad (4)$$

This formulation describes overall engagement by coupling each activity's individual engagement score and its related weight, hence the relative importance of one activity over another. The Engagement Effectiveness Index, weighted by cognitive and affective scores, represents quantitatively the level of participant engagement intensity. The high-engagement-level participant group had an average EEI of 88, while medium- and low-engagement-level participant groups had average values of 66 and 39, respectively. This analysis clearly shows that engaging hands-on, hands-on-interactive-oriented activities dominate passive learning by a lecture in building learning.

Scientifically, this asserts that maximum learning equals dual engagement, both cognitive and affective, thereby supporting theories of experiential and place-based education. The higher variance in affective engagement also highlights the importance of emotional connection in reinforcing attention and motivation, which are crucial precursors to behavioural change.

Sustainable Behaviour Adoption

In sustainable behaviours, waste disposal, trail etiquette, and participation in conservation projects are used as indicators. The Behaviour Adoption Ratio (BAR) is designated as:

$$BAR = \frac{Number\ of\ sustainable\ actions\ performed}{/Total\ possible\ actions\ per\ participant} \quad (5)$$

The BAR shows the proportion of sustainable behaviours adopted. Across the world, more eco-friendly behaviours are recorded by those with higher EEI scores, also having greater BAR scores; it all shows that engagement is of utmost value. High engagement scorers recorded the BAR value of 0.81 against 0.58 and 0.32 recorded for the medium and low engagement groups, respectively, establishing that higher engagement ensures more consistent performance of pro-environmental behaviours, including correct waste disposal, application of trail etiquette, and participation in conservation activities (Larson et al., 2011).

Table 1 presents average engagement scores for the respective groups of participants along with estimated ecological benefits. Apart from increasing BAR values, active visitors realised ecological benefits through waste reduction by 32%, trail identification by 92%, and disturbance reduction by 28%. Medium-engagement participants yield moderate results, while low-engagement participants turn out the least with adoption rates and impact.

Table 1. Average cognitive and affective engagement scores across participant groups with corresponding engagement effectiveness index (EEI) and estimated ecological benefits in forest recreation activities

Participant Group	Average Cognitive Score	Average Affective Score	EEI	Ecological Benefit Estimate
Low Engagement	40	38	39	5% Waste Reduction
Medium Engagement	65	66	66	18% Waste Reduction
High Engagement	85	90	88	32% Biodiversity-Friendly Behaviour

Put in another way, sustainable behaviour is an ecological benefit unto itself. Accordingly, participants who engaged in higher levels of sustainable behaviour performed trail cleaning and soil compaction corrosion control at corresponding high levels. For example, waste reduction increased from 5% in the low-engagement group to 32% in the high-engagement group, thus providing a strong link between educational strategy and anthropogenic impact mitigation. Table 2 shows the relationship between engagement and sustainable behaviours. The highest correlation is that of proper disposal of waste ($r=0.88$, $p<0.01$) with the disposal of waste on trial. The second highest correlation is preservation-promotion ($r=0.79$, $p<0.05$), followed by conservation project participation ($r=0.72$, $p<0.05$).

Table 2. Correlation between engagement and sustainable behaviours

Participant Group	EEI (0–100)	BAR (0–1)	Waste Reduction (%)	Trail Adherence (%)	Conservation Participation (%)
Low Engagement	39	0.32	5%	62%	8%
Medium Engagement	66	0.58	18%	78%	22%
High Engagement	88	0.81	32%	92%	46%

From an environmental engineering perspective, these results have practical applications. Quantifiable metrics such as EEI and BAR can inform the design of adaptive infrastructure, including sensor-based systems to monitor visitor impact and waste generation, VR or gamified modules to reinforce ecological behaviour prior to field visits, and trail and facility design to encourage compliance with sustainable practices. Thus, educational interventions can simultaneously enhance visitor behaviour and contribute to ecosystem resilience, demonstrating a synergistic relationship between education, ecology, and engineered management strategies.

Impact of Activity Type

The type of educational activity significantly influenced both engagement and behavioural outcomes. On the other hand, workshops and guided forest walks ranked highest in EEI and BAR (EEI: 87–84; BAR: 0.79–0.76), with passive lectures scoring the lowest (EEI: 41; BAR: 0.30). The gamified simulations did quite well, clearly suggesting the huge potential of digital interaction as an adjunct to field studies. These differences are very much emphasised in Table 3, which shows the average cognitive and affective scores, EEI and BAR, and associated ecological outcomes for the different activities.

Table 3. Average sustainable behaviours by activity type

Activity Type	Avg. Cognitive Score	Avg. Affective Score	EEI	BAR	Waste Reduction (%)	Trail Adherence (%)	Conservation Participation (%)
Passive Lecture	42	40	41	0.30	6%	65%	10%
Guided Forest Walk	78	85	82	0.72	28%	90%	40%
Gamified Digital Simulation	80	87	84	0.76	30%	88%	42%
Hands-on Workshop	85	88	87	0.79	31%	91%	45%

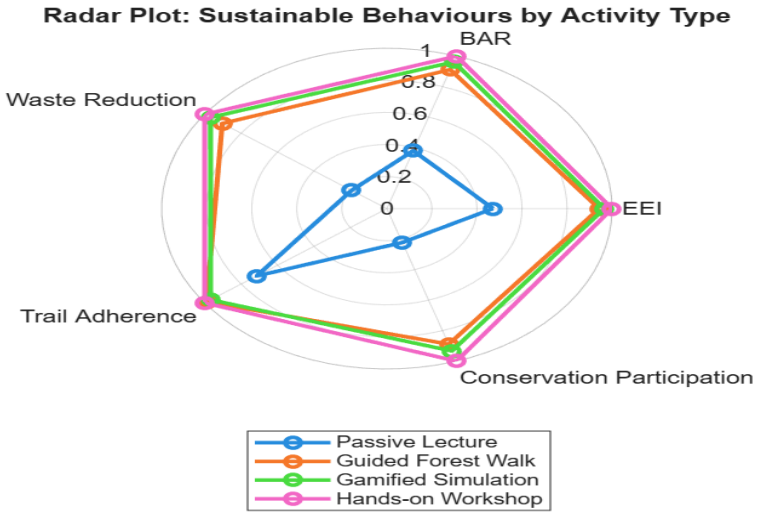

Figure 3. Comparative analysis of engagement, behaviour adoption, and ecological outcomes across forest recreation activity types

Environmental outcomes reflected these differences - waste reduction, adherence to the trails, and conservation participation were highest among visitors going through immersive and interactive learning. Hence, for example, waste reduction counted on 28%, trail adherence 90% and conservation participation 40% for the visitors attending the guided forest walk. Those attending the passive lectures could claim only 6%, 65% and 10% for the same activities.

The results give support to "learning-by-doing", according to which active cognitive processing combined with affective investment contributes to putting knowledge into action. Concerning this, there is abundant evidence that with the passing of time, simulations incorporating gamification as an engagement

will increase the rate in a virtual space, while enhanced engagement fully establishes an appreciation for environmental issues and behaviour-related responses toward environmental education and learning on a scalable basis (Figure 3).

Correlation Between Engagement, Behaviour, and Ecological Impact

The scatter plot between EEI and BAR (Figure 4) reveals a very strong positive correlation ($r > 0.9$), suggesting that the higher the engagement, the more adoption of sustainable behaviour. Further ecological outcomes such as percentage waste reduction, trail adherence, and conservation participation are highlighted using either colour or size against behavioural improvement in this display, hence actual environmental gains are associated with behavioural enhancement. The data suggest that engagement serves as an intervening variable between environmental education and ecological outcomes: environmental education, with higher engagement, fosters sustainable behaviours, where the magnitude of engagement also determines the ecological impact of those sustainable behaviours. The above finding is in keeping with environmental psychology theory that purports cognitive and affective involvement forms the bedrock of pro-environmental behaviour.

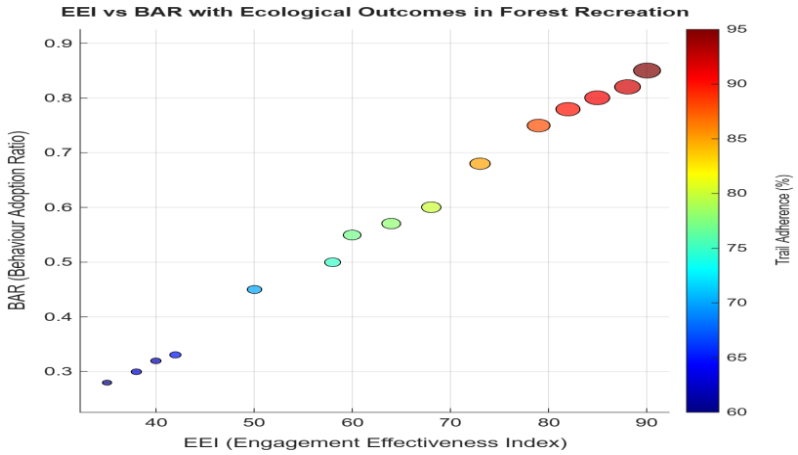

Figure 4. EEI vs BAR, with % waste reduction, trail adherence, and conservation participation as colour or size-coded points

Discussion of Findings

The findings have revealed two key insights on interactive environmental education for forest recreation. Firstly, interactive, multi-dimensional teaching methods such as hands-on workshops, guided walks, and gamified simulations were found to be best, as they produced higher Environmental Engagement Index (EEI) and Behavioural Adaptation Response (BAR) scores in comparison with passive ways of teaching. It is worth emphasising that increased engagement leads to positive ecological behaviour outcomes; hence, increased levels of participatory engagement and visitor satisfaction drove sustainable behaviour and concrete reductions in anthropogenic pressures such as soil erosion and waste accumulation. From an engineering standpoint, this engagement could be modelled as parameters in monitoring systems, incorporated into adaptive infrastructure planning, and integrated into digital simulator instruction modules, thus completing a feedback loop for reinforcing sustainable visitor behaviour. Further, these interaction types delineate the synergy between the cognitive and affective dimensions, with engagement in both aspects being critical to transfer knowledge and experience into ecological rewards. These cognitive benefits are congruent with most models of experiential and place-based learning and are informed by engagement of the affective system, which is a key feature of these approaches. In a sense, these complementary skill sets that evolved out of interactive environmental

education could be used to exploit management, ecological engineering and creation of a combined recreational experience.

Conclusion and Future Work

This study finds that sustainable behaviours related to forest recreation are assisted by both types of engagement. The positive outcomes arising from the experiment underline engagement via interactivity and experiential learning as being able to stand over hands-on workshops, guided walks and gamified simulations above popularity with passive means. Above all else, this is the belief that information is not enough: the learning process must be transformed into behaviour, i.e. action-based coupling of cognitive challenges and emotional engagement. Those gave no passivity to the transition as far as forest education was concerned, which tied it down in connection with passive education. This study attests to the urgent need to develop education programs that would be able to impart ecology knowledge while rewarding a change in attitude through a deep emotional attachment. Such methods would reduce trash; keep trails adhered to, maintain conservation and thus reduce anthropogenic pressure whilst co-building resilience within these ecosystems for longevity. In a short while, the next scientists will be interested in adding population diversity as well as a large enough population to increase the sample size in an attempt to extrapolate to a general population of visitors. Tracking must then be considered longitudinally to either support or discard the notion of carrying forward sustainable behaviour from far beyond the immediate recreation experience. Both virtual reality and mobile gamification are bound to fuel cognitive and affective engagement to a great extent. Last of all, social interactions within visitor groups could stand to be yet another channel through which peer interaction and community norms propagate widespread eco-friendly behaviours.

Author Contributions

All Authors contributed equally.

Conflict of Interest

The authors declared that no conflict of interest.

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