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*Systematic Review*

# Systematic Review of Research on Reality Technology-Based Forest Education

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**Abstract:** This study aimed to analyze the effectiveness of reality technology programs in forest education by systematically reviewing prior studies that have verified the effectiveness of reality technology-aided forest education content. Additionally, we checked the current status of reality technology content-based forest-related education. We searched for data on forest education using reality technology published until November 2022 in both domestic and foreign web-based academic databases. In total, 117 research papers were identified, and 13 were selected based on the data selection criteria. After systematic analysis, we inferred the following: First, most reality technology-based forest education programs use augmented reality (AR); the software is customized and developed for mobile devices because AR is effective in two-way communication owing to the nature of the technology. Second, forest education showed greater cognitive and affective effects when reality technology was used (cognitive effect: 71.4%; affective effect: 63%) than when it was not used. Third, forest education using reality technology produced more than 90% cognitive and affective effects (cognitive effect: 90%; affective effect: 100%). Therefore, forest education using realistic technology can have a positive effect indoors. Although these results are difficult to generalize, they can be used as basic data for future research on reality technology-based forest education.

**Keywords:** reality technology; forest education; augmented reality; virtual reality; cognitive effect; affective effect



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## 1. Introduction

Forests have grown in importance as carbon-absorbing resources. Knowledge and attitudes toward forests have become essential elements of the present day. The global community responded to the climate crisis with the 2015 Paris Climate Agreement [1]. Korea declared the "2050 Carbon Neutral" stance in October 2020, strengthening and utilizing the role of forests in responding to climate change [2]. Moreover, the revised Framework Act on Education in Korea, implemented in September 2021, states that all citizens receive ecological transformation education to cope with climate change [3]. The Framework Act on Education (2021) emphasizes the cultivation of knowledge and attitudes toward the ecosystem [3]. These measures reveal efforts to strengthen people's knowledge and capabilities in coping with climate crises through forest education.

According to a study by the National Institute of Forest Science, forest education refers to "education that recognizes the value of forests and fosters people who practice them for sustainable forests" [4]. Furthermore, according to Korea's legal definition, "forest education" means education for experiencing, exploring, and learning about various functions of forests to understand the importance of forests, acquire knowledge about forests, and develop a proper sense of value [5]. In particular, during forest education, forest experience refers to activities for all ages to directly and sensibly accept various elements of the forest through five sensory experiences in the forest to develop ecological sensitivity [6]. This study included all forest plants, wetlands, and rocks because it focused on learning about natural products composed of forest ecosystems and recognizing the value of forest ecosystems through Korea's legal basis and prior research.

Forest education is advantageous in several ways. It also has a positive effect on infant development by developing infant social skills, improving their ability to control emotions [7,8], and reducing problematic behavior [8]. Similarly, it benefits children and adolescents by reducing stress, improving health, and improving environmental sensitivity by helping them control their emotions [9–12]. It also effectively improves family health [13] and helps adults [14].

However, opportunities for forest education are gradually decreasing for various reasons, such as urbanization, the incidence of COVID-19, and the climate crisis. In particular, the measures surrounding COVID-19 have restricted outdoor activities and the gathering of people, leading to decreased participation in forest education. Currently, the number of participants in Korea's forest education program, which gradually increased from 2015 to 2019, has decreased by 50% from 6304 in 2019 to 3137 in 2020 [15]. Additionally, everyday access to forest education might have practical difficulties caused by weather and seasonal restrictions. When analyzing the use status and demand for forest education among adults, "accessibility" was selected as the most important consideration for all age groups when selecting forest education (42.1%) [16]. In addition, "lack of access to public transportation" was cited as the top inconvenience that hinders participation in forest education for all ages [4]. Thus, the biggest obstacle to participating in forest education was "going to distant forests".

Reality technology content can serve as an alternative and supplementary means for increasing accessibility to forest education. Realistic technology content refers to "a type of content that allows you to feel experiences and emotions similar to reality, and by implementing three-dimensional visual effects using new digital technology, you can manipulate or experience virtual digital content like a real object" [17].

In fact, as an added advantage, the scope of education can be expanded by enabling people to experience areas of the forest that are difficult to visit or the forest at various seasons and times [18] in a safe environment with increased interest because of reality technology. Nevertheless, confidence in the practical application of technology within the educational environment remains limited [19–24]. Hence, in order to proficiently implement forest education through the use of reality technology, a comprehensive review of prior research is imperative.

Research on education using real technology or the effects of forest and outdoor learning is being conducted, but there is no systematic review of research on real technology-based forest and natural education [25]. In contrast, a number of theoretical and systematic review studies have been conducted on the advantages and disadvantages of applying digital technology to the outdoor learning experience [24,26–30]. To the best of our knowledge, this is the first study to present a systematic review of the effectiveness of reality content in forest education.

In this study, we analyzed the implementation of forest education using reality technology by analyzing the literature for the cognitive and affective effectiveness of this mode of education and the technological trends that support it. First, we would like to analyze the effectiveness of forest education using realistic technology and discuss the importance of forest education. Next, we would like to assess the current status of forest education using realistic technology. We would like to know what technology is used to conduct forest education using realistic technology and what cognitive effects are measured. This result aims to provide basic data on forest education using realistic technology.

## 2. Materials and Methods

This study is a systematic review that analyzes the current status of intervention research along with the characteristics and effects of the said intervention by identifying outcome variables related to cognitive, affective, and psychological areas for application to forest education programs using reality technology.

### 2.1. Protocol and Registration

Literature selection was conducted according to the systematic review guidelines presented by PRISMA (Preferred Reporting Items for Systematic Review and Meta-analysis) [31,32]. The literature search strategy was based on Population, Intervention, Comparison, Outcome, and Study design (PICOS), written through a literature review. Studies in English and Korean were selected in the respective publishing languages. Distortion was measured using ROBINS-I, which was used for the random control groups.

### 2.2. PICOS and Eligibility Criteria

A systematic review was conducted on papers reporting forest education program intervention using reality technology, and key questions were specified using PICOS standards, as listed in Table 1. Before study selection, we established the eligibility criteria according to the PICOS framework.

**Table 1.** Eligibility criteria for study selection.

| PICOS Element | Setting | Inclusion Criteria | Exclusion Criteria |
|---|---|---|---|
| Population | People | | |
| Intervention | Natural environment education using virtual technology * (* Education to gain natural experience, acquire knowledge, and acquire proper knowledge and values about nature and the environment) | Education to use virtual technology and to develop attitudes and knowledge about nature/forest ecosystems/forests. | Biochemistry, Nursing, Health, and Medical Education |
| Comparator | (No restrictions) | | |
| Outcome | A quantitative assessment | | Research that did not conduct educational performance evaluation of participants, only qualitative evaluation, and only evaluation of virtual technology programs (satisfaction, sense of realism, etc.) |
| Study Design | (No restrictions) | | |
| Miscellaneous | | Study completed before November 2022 | A study written in a language other than English, in which the full text is not confirmed |

### 2.3. Search Strategy

This review was conducted by selecting keywords related to forest education interventions that use reality technology. The data search was performed on data published from June 2022 to November 2022 in major search databases such as the Education Resources Information Center (ERIC), EBSCO (Ipswich, MA, USA), Web of Science, ProQuest (Ann Arbor, MI, USA), PSTCinfo, PubMed, and Scopus. A manual search was performed using the reference lists of the searched papers (Table 2).

**Table 2.** Search keywords.

| | (AND) | (OR) | Keywords |
|---|---|---|---|
| **P** | | | NA |
| **I** | Reality technology | A term for Reality technology | "virtual reality" OR "VR" OR "augmented reality" OR "AR" OR "mixed reality" OR "MR" OR "extended Reality" OR "XR" |
| | | Implementation Method | OR "CG" OR "3D" OR "360" OR "panorama video" OR "4D" OR "5G" |
| | | Words that mean virtual experience and education | OR "immersive experience" OR "immersive technology" OR "immersive virtual environments" OR "virtual nature" OR "virtual forest" OR "virtual scenery" OR "virtual environment" OR "virtual space" OR "virtual learning" |
| | | Instrument and equipment related words | OR "VLE" OR "IVE" OR "iPAD" OR "HMD" OR "cardboard" OR "oculus rift" OR "Samsung gear" OR "VIVE head mounted display" |
| | Education contents | Educational topics | "forest education" OR "environmental education" OR "environmental studies" OR "nature of science" OR "ecology" OR "life science" OR "sustainable education" OR "eco-education" OR "nature-specific" OR "biology education" |
| | | Education contents | OR "wildlife" OR "climate change" OR "life cycle" OR "ecosystem" OR "endangered species" OR "endangered" OR "green sustainable" OR "biodiversity" |
| | | A place of education | OR "outdoor science" OR "outdoor learning" OR "observation learning" OR "outside the classroom" OR "nature center" OR "arboretum" |
| | | A method of education | - |
| | Education | Education | "pedagogy" OR "pedagogical" OR "education" OR "training" OR "instruction" OR "edutainment" OR "instruction" OR "teaching" OR "inquiry" |
| **C** | | | NA |
| **O** | Effect | A word for educational effect | "learning outcomes" OR "learning achievements" OR "learning effect" OR "learning effectiveness" OR "effect of learning" OR "learning performance" OR "learning gains" OR "learning performance" OR "learning gains" |
| | | Frequently used indicators and associated representations | OR "cognitive" OR "concept" OR "self-directed" OR "scientific process" OR "problem solving" OR "scientific knowledge" OR "attitude" OR "intentions" OR "cooperative" OR "collaborative" OR "interconnectedness with nature" OR "inclusion of nature in self" OR "INS(Inclusion of Nature in Self)" OR "intentions" OR "pro-environmental behavior" OR "socio-emotional" OR "Body transfer" OR "Spatial presence" OR "perceived spatial presence" OR "nature-friendly" |
| **S** | | | NA |

VR, virtual reality; AR, augmented reality; MR, mixed reality; XR, extended reality; GC, computer-generated; VLE, virtual learning environment; IVE, immersive virtual environment; HMD, head-mounted displays.

*2.4. Study Selection*

In total, 3069 cases were identified in the databases: 1122 in Web of Science, 345 in PubMed, 1433 in Scopus, and 169 in ERIC databases (ProQuest). Using EndNote, 294 copies were removed, reducing the number to 2775, and 2651 papers were excluded after checking the titles and abstracts. Two investigators (S.C. and J.C.) independently screened the full texts of 117 studies, and contrasting assessments by the two reviewers were resolved by the other investigators (S.H.). All 117 documents were checked, and those that met the exclusion criteria were removed. For example, in 100 cases, either quantitative evaluation was not conducted, reality technology content was not used, full textual confirmation was not possible, or educational topics were inappropriate. Finally, 13 documents were selected by collecting the literature that met the required conditions.

### *2.5. Data Extraction*

Two authors used the same data extraction method to ensure precise and unbiased processing. The following data were extracted from each study: study information (first author, year of publication, and country), sample (participant characteristics, sample size, and age), intervention (activities, duration, characteristics, and reality equipment), outcomes (cognitive and affective effects and significance), control group, and study design.

An analytical framework was prepared to systematically analyze the contents of the final 13 documents, and three researchers independently analyzed the subjects, research design, intervention characteristics, and results. Subject characteristics were classified under all subjects, and intervention characteristics were set as forest-based education programs using reality technology. As for the results, cognitive domain, affective domain, and other effect variables were classified. The percentage of significant positive effects on cognitive and affective outcomes (%p) and the percentage of both significant and non-significant effects on positive outcomes (%p + m) were calculated. The results of each category were compared.

### *2.6. Methodological Quality Assessment*

An overall methodological quality evaluation was conducted using ROBINS-I. ROBINS-I is used to evaluate nonrandomized controlled trials (NRCT) studies. ROBINS-I is divided into pre-invention, at invention, post-invention, and overall risk of bias. Pre-intervention consists of (1) bias due to confounding and (2) bias in selection of participants into the study. At intervention is (3) bias in classification of intervention. Post-intervention includes (4) bias due to deviations from intended interventions, (5) bias due to missing data, (6) bias in measurement of outcomes, and (7) bias in selection of the reported result. Finally, (7) overall risk of bias is divided into seven areas.

Two authors (S.C. and J.C.) continued to assess the risk of bias according to the Cochrane Handbook, and the results are as follows (Figure 1) [14]. Domains were evaluated at five risk levels for bias: "low risk", "moderate risk", "serious risk", "Critical risk", and "No Information".

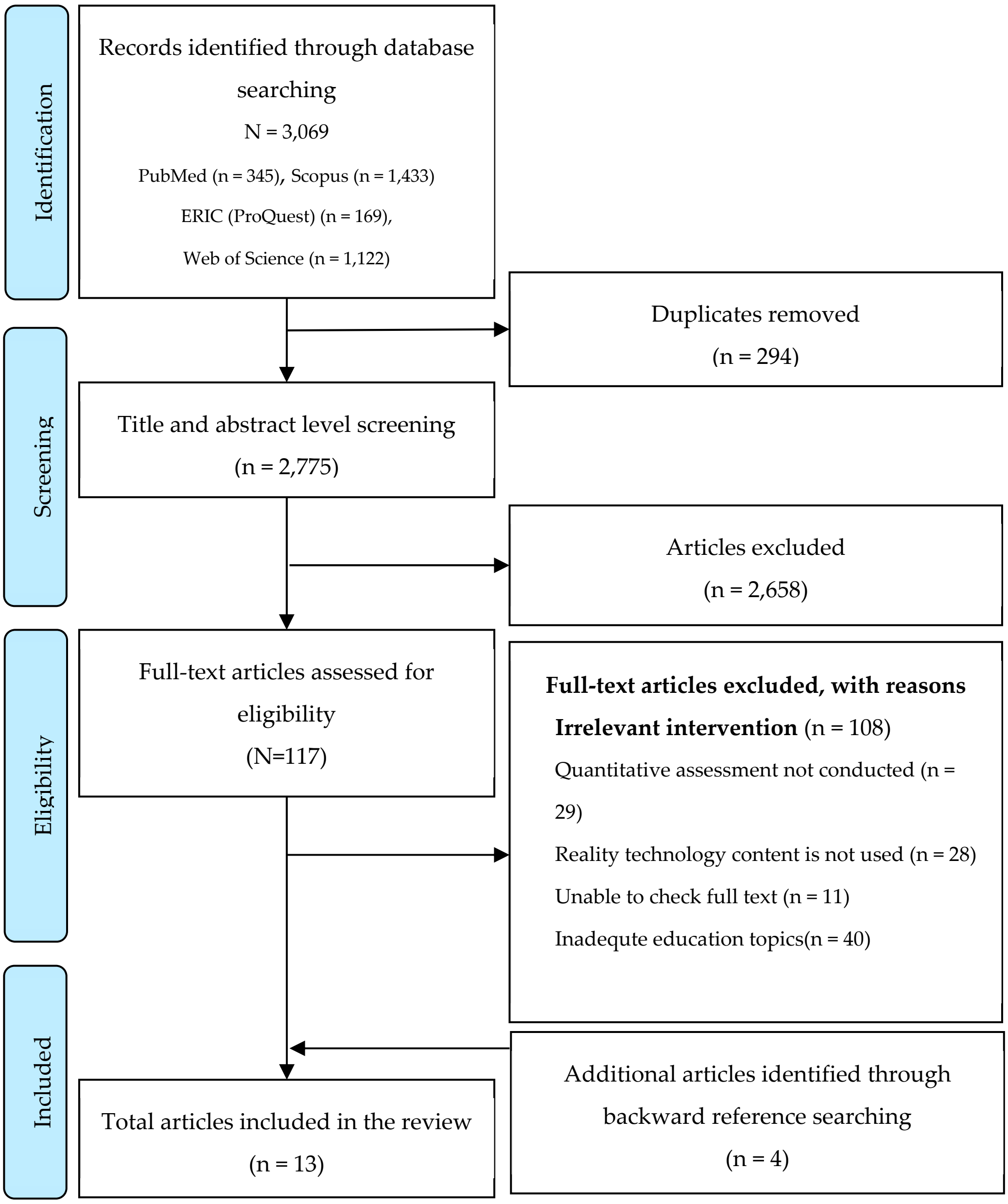


**Figure 1.** Flow diagram illustrating the selection process.

## 3. Results

### *3.1. Study Characteristics*

In total, 13 studies were included in this systematic review, and their research characteristics are shown in Table 3. The total number of participants in the 13 studies was 938, of which 409 used reality technology. The number of participants in various studies ranged from 21–263. Demographically, seven studies were conducted exclusively on elementary school students and three studies each for middle school students and adults. Most studies were conducted on individuals with general characteristics.

The intervention program used reality content to educate the participants regarding the environment, plants, animals, and rocks belonging to the forest-based ecosystem and was administered more than once in all studies. A closer examination of the educational contents shows that seven studies dealt with land ecosystem-related topics, two studies with geological topics, and four with wetland and pond ecology, species, and plants. Topics covered for terrestrial ecosystems include reforestation, garden plants, environment, plant growth, insect life and history, endangered species ecology, plant structure, and physiology. Geological topics explained rock formation and weathering, and education on wetland ecosystems included topics on the ecological environment and species of aquatic ecosystems.

In forest education research using real technology, most of the interventions were performed once. More than one intervention was made in only two of the 13 studies. The intervention time ranged from at least 25 min to a maximum of 120 min, and the average time for one use of reality technology in a study with educational information was 72 min. There were no significant differences in effectiveness based on the frequency of interventions and over time. Two studies conducted forest education using reality technology for 120 min, one study for 90 min, three studies for 60 min, three studies for <60 min, and more than half of the studies for >60 min. Five indoor studies were conducted in classrooms, and five outdoor studies were conducted in places such as school campuses, national parks, and gardens. There is no special difference between outdoor and indoor training. But there is a difference in some ways. Outdoor training uses a mixture of real space and virtual technology.

The most commonly used type of technology was AR. The intervention programs of all but 5 of the 16 studies used symptom reality (AR), and the remaining studies used immersive VR. Among the software used, one study had a 2D interface design [33], one study had a 360° panorama image [34], and 14 studies had 3D images [23,35–44]. The software was customized and developed for all studies, except for two that used commercial programs [37,41]. Reality technology content was designed to provide a virtual visual environment when receiving forest-related education that allows participants to more actively observe and participate in learning by responding using a touch screen or AR marker.

In terms of study design, all 13 studies were found to be pre-posttest design. Therefore, in this study, only ROBINS-I was used to measure the risk of bias in non-randomized controlled studies. Among the countries where these studies were conducted, eight were conducted in Taiwan/China, two in the United States, two in Greece, and one in Singapore. Six of the 13 studies were conducted after 2020: Two in 2019, two in 2016, one in 2015, and two in 2014. Research on using reality technology for forest education began in the late 2010s, and since the 2020s, research on using reality technology for forest education has been attracting increased attention.

An investigation of the characteristics of the academic field pertaining to the journals where these papers were published revealed that eight studies were published in educational journals, with most of the papers being published in this journal category. This includes journals on social, computer, and digital education. In particular, among the many existing fields of digital learning, reality technology has been extensively studied in an attempt to apply it to education. In addition, one journal published VR-related content, and four journals published nature- and environment-related content.

### 3.2. Outcomes

They classified the educational target areas as cognitive, affective, and psychological [45–47]. In forest education, cognition is divided into knowledge, definition of attitude function, and psychological participation. In this study, the results were categorized and organized according to cognitive and affective areas. The results of the quizzes and knowledge were grouped into cognitive areas, whereas areas such as "attitudes" and "functions" were classified into affective areas. The mental component was excluded because it had no effect. The affective domain has various meanings in different pedagogies. He mentioned "attitude", "interest", "value", "preference", "self-esteem", and "anxiety" as affective areas [45], whereas He defined affective areas as emotions that include elements such as "attitudes" and "beliefs" as concepts different from cognition [48]. He stated that "emotions", "attitudes", and "beliefs" are sub-areas [49], and domestic studies cited "motivation", "attitude", "self-efficacy", and "anxiety" as sub-factors [50,51]. Based on previous studies, areas containing "emotions", excluding cognitive areas, were grouped into affective areas and analyzed. Therefore, sub-areas such as "enjoyment", "motivation", "perception/perception", "engagement", "attitude", and "challenges" were included in the affective area.

### 3.2.1. Cognitive Domain

In total, 13 studies reported the effects of the cognitive domain. The measurement tool was a quiz related to the content of the class; all self-produced tools were used. The measurement of the results of the cognitive domain according to the intervention was assessed immediately after class (16) and after delay (4); in total, 20 tests had been administered. Among them, nine studies reported that they were effective as a result of testing the cognitive knowledge immediately after class [33–39,42,43], and four studies [23,37,40], reported that they were effective after class. Hence, it can be observed that there is a notable improvement in cognitive abilities immediately following a forestry education session utilizing reality technology.

The participant demography showed that seven studies were conducted among elementary school students (accounting for 37.5% of the included studies [23,33,35,36,38,41,43], five studies among middle school students (31.25%) [34,37,39], and four studies among adults (25%) [40,42,44]. Among the devices used, most of the studies used mobile devices [33–37,39–44,52], two studies used computers [23,42], and one study used a head-mounted display (HMD) [42].

Analyzing the studies according to the composition of the control groups showed that six studies included a control group to conduct education in the traditional manner [36,37,39,40]. These studies compared the intervention groups that participated in forest-based education using reality content with groups that participated in lecture-style education using traditional learning aids such as corporation prints or existing textbooks. For example, one of the studies with a traditional control group conducted self-learning and commentator guidance using AR [39] in the intervention group. In addition to the traditional teaching method, one study used AR-free mobile devices for the control group [33], one [37] used web pages, one used video education [23], and one used textbooks and guide maps at home [43] (excluding [38]).

Eight studies reported that learning using reality technology content has a more significant effect on the cognitive domain than when using the generally used traditional teaching methods [36,37,39,40]. Compared with one study using mobile devices without AR and other studies using printed materials and webpages, education using reality technology had a cognitive effect [33,36]. One study reported that the use of virtual ecosystems through reality technology when receiving education has a greater cognitive effect than that of studies that did not have this feature [34]. In another study, general teaching guidance and AR-based education were compared, but no significant cognitive improvement was observed immediately after class, although it improved significantly later [40]. Compared with other technologies such as mobile devices and videos, reality technology was shown to be significantly more effective [33,43]. Both self-learning using AR and commentator guidance yielded significant cognitive results [39]. Therefore, it can be argued, in the context of forestry education utilizing reality technology, that it is more effective in cognitive enhancement compared to conventional pedagogical methods.

### 3.2.2. Cognitive Domain Categorized Intervention

Significant effects were confirmed by dividing the cognitive effects into educational age, reality technology used, education place, and education time. The results are summarized in Table 4. First, on analyzing cognitive differences according to educational age, we found that six studies (75%) had reported cognitive effectiveness in elementary school students, six (85.71%) in middle school students, and three (60%) in adults. In addition, although not significant, five studies (two among elementary school students (25%), one among middle school students (14.29%), and two among adults (50%)) reported raised scores (Table 4).

**Table 3.** Main characteristics of the included studies.

| | First Author | Country | Participant | N | Intervention | Reality Technology (Equipment) | Time | Group | Outcome Measurement | Study Design | Study Place |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Tosti H.C. Ching (2014) [33] | Taiwan/China | Elementary school students | 57 | (n = 29) Aquatic ecosystem ecological environment and biological species education using AR-applied mobile devices | AR (mobile device) | 120 | (n = 28) mobile | Self-produced quiz (*), ARCS (*) | Pre-posttest design | School campus (outdoor) |
| 2 | Tien-Chi Huang (2016) [39] | Taiwan/China | Middle school students | 21 | (a) (n = 7) Plant and environmental education in the AR system for commentor guidance, (b) (n = 7) Plant and environmental education in the AR system for self-learning guidance | AR (mobile device) | NI | (n = 7) Traditional learning | (1) Self-produced quiz (*), experiential activity questionnaire(ENG (*), CHA (/), INT (/), CMP (/)) (2) Self-produced quiz (+), experiential activity questionnaire(ENG (/), CHA (/), INT (/), CMP (*)) | Pre-posttest design | Botanical garden (outdoor) |
| 3 | Rong-Chi Chang (2014) [23] | Taiwan/China | Elementary school students | 55 | Using AR Flora System to Educate Plant Growth | AR (computer) | 30 | (n = 27) Video | Self-produced quiz (after class (+/) delayed (*), learning motivation (*) | Pre-posttest design | Classroom (indoor) |
| 4 | Wernhuar Tarng (2015) [43] | Taiwan/China | Elementary School students | 60 | Using AR with GPS to impart education on the life of butterflies on campus | AR (mobile device) | NI | Education on the life of butterflies on campus at home | Self-produced learning effectiveness (*), self-produced attitudes (+/) | Pre-posttest design | School campus (outdoor) |
| 5 | Kuo-Liang Ou (2021) [42] | Taiwan/China | Adults | 80 | (a) Training on ecology and environmental protection of endangered species through VR using HMD (b) Educated on ecology and environmental protection of endangered species through VR using computer | (a) VR(HMD) (b) VR (computer) | NI | NI | (1) Self-produced learning effectiveness (*) (2) Self-produced learning effectiveness (*) | Pre-posttest design | Classroom (indoor) |
| 6 | Kuo-Liang Ou (2021) [34] | Taiwan/China | Middle school students | 42 | (n = 21) Experience virtual wetland ecosystem for learning using VR and receive training | VR (mobile device), 360° panorama image | 60 | (n = 21) Textbook | Learning effectiveness (*). learning motivation (*) | Pre-posttest design | Classroom (indoor) |
| 7 | Tien-Chi Huang(2019) [38] | Taiwan/China | Elementary school students | 70 | (n = 35) Training on rock formation and weathering based on Taiwan's National Geopark using AR | AR (mobile device) | 60 | (n = 35) Textbook and guide map | Kolb's learning style (*), ARCS (+/) | Pre-posttest design | National park (outdoor) |
| 8 | Kamarainen, Amy M (2013) [41] | USA | Elementary School students | 71 | Training on pond life and ecosystem using AR | AR (mobile device) | 60 | NI | Self-produced quiz (+), | Pre-posttest design | Pond (outdoor) |
| 9 | Yu-Cheng Chien (2017) [35] | Taiwan/China | Elementary school students | 45 | Use AR to educate plant organs and classificationplant observation | AR (mobile device) | 35 | The same education without AR | Self-produced quiz (*) | Pre-posttest design | School campus (outdoor) |
| 10 | Emmanuel Fokides (2020) [36] | Greece | Elementary School students | 49 | Training on the ecology and environment of endangered species through VR using SVs (physical video) | VR (mobile device) | 90 | Printout, website | Self-produced quiz (+), evaluating user experience: Fun/enjoyment (*), motivation (*),ease of use (perception) (*) | Pre-posttest design | Cclassroom (indoor) |
| 11 | Kyra Wang (2021) [44] | Singapore | Adults | 85 | (n = 37)AR is used to play mini-games on environmental and climate issues (forest afforestation) | AR (mobile device) | NI | NI | Self-produced quiz (+), TPB (attitude (*)) | Pre-posttest design | Real-world (outdoor) |
| 12 | Juan Garzon (2020) [40] | USA | Adults | 40 | (n = 20) Training on hydroponic cultivation of ponds using teaching guidance and AR | AR (mobile device) | 25 | The same education without AR | Self-produced quiz (after class (+/), delayed (*)), IMMS (learning motivation) (*) | Pre-posttest design | Agritourism farm (outdoor) |
| 13 | Emmanuel Fokides (2020) [37] | Greece | Middle school students | 263 | (a) Educate the structure and physiology of plants using tablets and commercial apps (b) (n = 53) Educated using tablet and teachers using their own non-commercial apps | AR (mobile device) | 120 | Traditional learning, printout | (1) Self-produced quiz (after class (*), delayed (*)), evaluating user experience: Fun/enjoyment (*), motivation (*), ease of use (perception) (*) (2) Self-produced quiz (after class (*), delayed (*)), evaluating user experience: Fun/enjoyment (*), motivation (*), ease of use (perception) (*) | Pre-posttest design | Classroom (Indoor) |

ENG, engagement; CHA, challenge; INT, interest; COM, competency; ARC, attention, relevance, confidence, and satisfaction; TRB, theory of planned behavior; IMMS, instructional materials motivation survey)/*fun/enjoyment and interest are in the same category. * "ease of use" is categorized by perception.; *: significant effect; +/: nonsignificant effect on positive outcome; /: nonsignificant effect.

**Table 4.** Outcomes according to the intervention type conducts in the included studies.

| | Reality Technology Type | | | | Place of Education | | | | Age of Education | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AR | | VR | | Indoor | | Outdoor | | Elementary School Student | | Middle School Student | | Adult | |
| | %p | %p + m | %p | %p + m | %p | %p + m | %p | %p + m | %p | %p + m | %p | %p + m | %p | %p + m |
| **The cognitive domain** | 64.29 | 100 | 100 | | 90.00 | 100 | 60.00 | 100 | 75.00 | 100 | 85.71 | 100 | 60.0 | 100 |
| **Affective domain** | 66.67 | 71.43 | 50 | 50 | 100 | | 42.86 | 57.14 | 71.43 | 100 | 60 | 60 | 100 | |
| **Other Effect (emotional)** | 33.33 | 100 | 33.33 | 100 | 25 | 75 | 85.71 | 100 | 50 | 100 | 33.33 | 66.66 | 66.66 | 66.66 |
| Included studies | [19,22,31–33,36,38,39,44,52] | | [11,22,34] | | [11,32,34,36] | | [19,31,33,38,39,39,43,44] | | [11,19,31–33,43,52] | | [22,36,38] | | [34,38,44] | |

%p: ratio of significant effect; %p + m: ratio of both significant and nonsignificant effect on positive outcome; AR, augmented reality; VR, virtual reality.

In this study, intervention using AR showed cognitive improvement in all studies [19,23,37–40,43,44,52]. 64.29% (n = 9) reported statistically significant cognitive improvement, and 35.71 (n = 5) found that studies reported cognitive improvement, although not statistically significant. On closer analysis, two studies using AR reported that the cognitive improvement was not significant when measured after participating in education and immediately after class but was significant after class participation [23,40]. Two studies showed significant improvement in the cognitive domain during class [35,43]. All four studies that included VR (100%, n = 4) reported significant effects. Research on the use of large screens showed no cognitive effects [44]. Therefore, AR seems appropriate to achieve cognitive effects through forest education using realistic technology.

Among the studies in this review, 10 were conducted indoors, nine (90%) of which reported that the impact on the cognitive domain was effective; the other reported that the cognitive domain increased but the increase was not significant. Of the studies conducted in outdoor or real-world environments, six (54.55%) reported that the interventions were effective. This result confirmed that forest education using real technology is effective in obtaining knowledge about forests, even when conducted indoors. Four cognitively effective studies [33,36,37] used reality technology content for longer than the average usage time of 72 min, and four used it for shorter than the average usage time of 72 min [23,34,38,40]. Therefore, we inferred that the cognitive effect did not differ significantly because of usage time.

### 3.2.3. Affective Domain

Out of 13 studies, 10 reported effects on the affective domain, and 12 interventions were reported to impact the affective domain [23,33,34,36–40,43,44]. Twelve measurement tools were used in the affective area and divided into the following sub-areas: "pleasure" ("interest"), "motivation", "perception" ("recognition"), "participation", "attitude", and "challenge. Of the 10 studies that measured the affective area, six measured multiple sub-areas [36,37,39,40,44], and the other five measured only learning motivation items [23,33,34,38,40]. To measure the domain of justice, various tools were employed, including custom-made instruments, the ARCS (Attention, Relevance, Satisfaction, Confidence) model tool [53], the Experience Evaluation Survey [54], the Theory of Planned Behavior (TPB) [55], and RQ3 [56]. The number of affective subfactors measured was five (33.33%) in elementary school students, 15 in middle school students (55.65%), and three in adults (11%). The sub-factors of the affective domain were measured the most for middle school students. The affective area was measured in 10 studies that used AR [23,33,34,37–39,42,44] and in two studies that used VR [36,42]. The main devices used were mobile devices [33,34,36–40,43,44] and computers [23].

In total, 10 studies were effective in the affective domain [23,33,34,36,37,39,40,43]. The areas that have been measured in most studies and found to be effective in the affective area were "motivation" and "interest". Four out of six studies were effective for "interest." All studies that were reported to be effective in "interest" were characterized as more effective than traditional teaching methods [36,37,44]. This aligns with prior research [57]. "Motivation" was measured in nine studies, six of which showed statistical significance [23,33,34,36,37,40] and one did not [38], although the results were improved. "Perception/recognition" was measured in six studies and was effective in four studies [37,39,44] and not effective in one study [39]. "Participation" was reported to be effective in one of the two studies [39] in which it was measured, and "attitude" was reported to be effective in another [44]. "Challenge" was measured in two studies but was reported to be ineffective [39]. Most studies measuring affective areas have used traditional learning methods [34,36,37,39,40] conducted as lectures using existing textbooks. Studies were characterized by comparing groups that used traditional teaching methods with groups using laptops and webpages, respectively [37]. In addition, one study trained using mobile devices [33], one using textbooks and guide maps [38], and one [23] using videos. One study was conducted without a control group [44]. A closer examination of Study 7 showed that when a teacher walked around a national park explaining what to observe and where to go, the experimental group used reality technology to observe the objects, whereas the control group used textbooks and guide maps to observe the objects. In that study, the affective area improved when textbooks and guide maps were used; however, this was not significant [38]. Mobile devices using AR were significantly more effective in motivating students than the use of mobile devices or being trained through video [23,33]; additionally, mobile devices with AR were more effective in motivating them than were traditional classes [36,37,40]. In the case of self-learning and commentator guidance using AR, compared with that of the control group with traditional education, it was not effective in inducing "interest" or exhibiting a spirit of "challenge" [39]. However, self-learning using AR was effective in leading "participation", and commentator guidance was effective in "perception/recognition" [39]. A study that analyzed afforestation education using AR games showed a significant increase in "perception" and "attitude" [44]. Therefore, when utilizing augmented reality (AR), it becomes evident that it is more effective in motivation compared to other mobile devices and is also effective in perception/cognition.

#### 3.2.4. Affective Domain—Categorized Intervention

Among the studies that reported a significant effect on the affective domain, five (55.56%) reported a significant effect in elementary school students, nine (60%) in middle school students, and three (100%) in adult participants. Although the scores for the interventions for elementary school students increased, two were not significant and two were reported to be ineffective. In addition, six cases reported that the intervention for middle school students was ineffective, accounting for 40% of the total interventions administered. We found that middle school students showed the greatest arbitration in the affective domain (Table 4).

Among those who used AR, 14 (66.67%) participants reported that it had a significant effect on the affective domain, and six (28.57%) reported that it had no effect. In studies using VR, three studies reported that it was effective (50%), and three studies reported that it was not effective. An indoor study reported that 10 (100%) studies were effective in the affective domain, whereas only eight (44.44%) studies conducted outdoors or in the actual environment were reported to be effective (Table 4).

#### 3.2.5. Other Effects

In addition, these studies also analyzed the psychological domain, which revealed both positive and negative emotions in the participants. Four interventions were administered in two studies and investigated using reality technology content [39,42]. To measure the psychological domain, the studies used either the self-produced tool made in reference to the Guide in Management of Analysis (1997) or the emotion self-assessment questionnaire, as was appropriate [58–60].

Only one of the four studies reported significant psychological changes after participation in forest-based education using reality technology. This was the result of comparing traditional learning methods with experimental groups using only AR for the control group, and a psychological effect was detected only when the commentator's guidance was received during self-learning using AR [39]. Participants who underwent self-learning using AR for the same training did not show a significant difference in the psychological domain, although they did show an improvement [39]. The results of the psychological effects of HMD VR and desktop VR without controls reveal that both HMD VR and desktop VR reported low anxiety [42], although this result was not significant. However, this study measured "anxiety", which is considered a disadvantage of using VR. However, the "anxiety" level was not high, which is a vital revelation; therefore, VR usage for forest education was reported to be safe as it did not cause anxiety.

### *3.3. Methodological Quality Assessment*

As a result of the quality evaluation of the studies, 13 NRCTs (non-randomized controlled trials) were conducted using ROBINS-I (Table 5). The methodological quality assessment was conducted to assess the bias in the final stage. In the pre-intervention area, the studies that reported confusion among the participants in the experimental and control groups were evaluated as medium or high risk, and those with no potential confounding factors were judged as low risk. Low means that the research is not biased and that the reliability of the research results is high.

**Table 5.** Risk of bias non-randomized controlled trials using the ROBINS-I tool.

| | Pre-Intervention | | At Intervention | Post-Intervention | | | | |
|---|---|---|---|---|---|---|---|---|
| First Author (Year) | Bias Due to Confounding | Bias in Selection of Participants into the Study | Bias in Classification of Interventions | Bias Due to Deviations from Intended Interventions | Bias Due to Missing Data | Bias in Measurement of Outcomes | Bias in Selection of the Reported Result | Overall Risk of Bias |
| Tosti H.C. Ching (2014) [19] | Low | Moderate | Low | Moderate | Low | Serious | No information | Serious |
| Tien-Chi Huang (2016) [39] | Low | Low | Low | Moderate | Low | Serious | No information | Serious |
| Rong-Chi Chang (2014) [23] | Low | Low | Low | Moderate | Low | Serious | No information | Serious |
| Wernhuar Tarng (2015) [43] | Low | Low | Low | Low | Low | Serious | No information | Serious |
| Kuo-Liang Ou (2021) [42] | Moderate | Low | Low | Low | Low | Serious | No information | Serious |
| Kuo-Liang Ou (2021) [34] | Low | Low | Low | Moderate | Low | Serious | No information | Serious |
| Tien-Chi Huang (2019) [38] | Moderate | Critical | Low | Moderate | No information | Serious | No information | Critical |
| Kamarainen, Amy M (2013) [41] | Low | Low | Low | Low | Low | Serious | No information | Serious |
| Yu-Cheng Chien (2017) [35] | Low | Low | Low | Moderate | Low | Serious | Low | Serious |
| Emmanuel Fokides (2020) [36] | Serious | Critical | Low | Serious | Serious | Serious | No information | Critical |
| Kyra Wang (2021) [44] | Low | Moderate | Low | Low | Low | Serious | No information | Serious |
| Juan Garzon (2020) [40] | Low | Low | Low | Moderate | Low | Serious | No information | Serious |
| Emmanuel Fokides (2020) [36] | Low | Low | Low | Low | Low | Serious | No information | Serious |

In the arbitration area, all studies were judged to have specified clear activities for each group and performed arbitration; therefore, all were evaluated as low risk. In the post-intervention area, most studies were evaluated as low risk when no participants or data were missing, and studies with difficulty completely blocking disturbance due to the nature of the intervention were evaluated as medium risk.

## 4. Discussion

### *4.1. Cognitive Domain*

The participants who were measured for cognitive effect mostly comprised elementary school students (37.5%), and 75% of the interventions reported that they had a significant effect. Middle school students also reported significant cognitive effects (85.71%). This result differs from those of previous studies, which stated that ecological knowledge is best learned in elementary school [61].

Reality technologies that produced cognitive effects were AR (64.29%, n = 9) and VR (100%, n = 4); hence, the effect of both interventions was significant. For the cognitive domain, 90% of the studies conducted indoors reported cognitive improvement; therefore, cognitive improvement was more likely in interventions administered in indoor studies than in studies conducted outdoors or in real-world environments. Based on this result, we infer that forest education can produce a cognitive effect using reality technology indoors, even if not conducted outdoors. Furthermore, the average usage time for reality technology was irrelevant to the cognitive effects. Most studies have reported that learning using reality technology content, as in previous studies, has been effective in the cognitive domain [20,24].

### 4.2. Affective Domain

The affective area was mainly mediated by middle school students (55.65%), and many studies had a significant effect on interventions for middle school students (60%, n = 9). Although the sample size was small, the affective area for adults also showed significant effects. Among the affective areas, the motivation and interest subareas were the most mediated. Interest had a significant effect compared with that of traditional teaching methods (60%) [22], and many studies reported that motivation had a more significant effect in the experimental groups than in the control group (77.77%). Furthermore, the difference in the effect for VR usage was not significant among the groups, and 66.67% (n = 14) of the participants reported an affective effect for AR. The affective domain also showed affective effects for all studies conducted indoors, and many studies reported more effectiveness for indoor studies than for those conducted outdoors or in actual forest locations.

### 4.3. Use of Reality Technology and Future Scope

Research on reality technology has been actively conducted in recent years, and in addition to forest education, it is actively underway in other areas of education. In particular, in Korea, digital textbooks are used to provide education using reality technology in schools. Based on the advances and usefulness of reality technology, we believe that more research on forest-based education using reality technology will be conducted in the future.

Most of this study used AR. This seems to be because it is easier to learn in both directions than in this VR, and various variations can be added [30,62]. AR seems to be effective in both cognitive and affective domains because it can be directly involved. It is also revealed in the characteristics of reality technology that interactive learning is more effective than unilateral learning in education [52].

Even as expectations for positive outcomes as a result of implementing reality technology are high, several concerns still exist; therefore, the reliability of these results must be increased by conducting continuous research in the future. Moreover, this study was based on papers collected in English. However, many studies on forest education using realistic technology were selected in Taiwan (8). This can be a limitation on the global scalability of the results of this study. However, this may mean that research related to education using realistic technology is being conducted with interest in East Asia. Future studies suggest that studies from various countries should be included. Furthermore, deriving results for a specific object or the same intervention was not possible in this study because the factors of the research design, such as the subjects, intervention methods, control groups, and test indicators of the studies, were diverse and subdivided. Nevertheless, the significance of this study is that it confirms the typification of intervention characteristics. Furthermore, this study represents the inaugural systematic literature review assessing the efficacy of forest education through the utilization of reality technology. Through the results of this study, it was confirmed that forest education using realistic technology has a cognitive and emotional effect.

Through the results of this study, realistic technology is expected to offset the biggest obstacle to the use of forest education, "uncomfortable access" [6,16]. It will be a way for more people to participate in forest education [63]. Anyone can participate in forest education anywhere because they can experience realistic technology anytime, anywhere, with a machine. This means that if forest education using realistic technology is activated, people who are unable to go to the forest due to disabilities will be able to enjoy forest education using realistic technology. It is also expected that people will be able to participate in forest education even in epidemic situations such as COVID-19.

However, the results of the current systematic literature review are still too early to generalize, and further verification through continuous research is needed in the future.

Based on this study, another study should be conducted later to confirm the effectiveness of forest education using realistic technology in the field. In addition, in this study, we saw effects related to "education", such as cognitive and affective areas using realistic technology. However, many people have not seen the effects of psychological and emotional areas, which are a concern when using realistic technology. This needs to be addressed in future studies.

### *4.4. Methodological Quality Assessment*

All studies where the participants knew their intervention and evaluation methods and were evaluated using self-reported questionnaires were evaluated as high risk, and studies whose protocols had been registered before the start of the study were judged to be low risk, although most of the information had not been specified. "Serious" came from the area after the intervention because the effectiveness assessment was mostly measured using self-report. These methods may reduce the reliability of research results and cause bias [64]. This requires determining interventions using high-reliability indicators to reduce the risk of bias in outcome measurements. Therefore, when evaluated based on overall distortion, most of the results were judged to be biased in the biased part of the measurement; however, this did not seem to have a serious impact.

## 5. Conclusions

This study conducted a systematic review to determine the effectiveness of forest education using reality technology and the current status of its use. The main conclusions of this study are as follows:

First, regarding the current status of forest education using reality technology, most studies that we (70.58%) examined used AR as the preferred type of reality technology. More than 90% of the software was customized for educational programs, and 3D accounted for 88.23% of the software interface design. Most of the study was conducted after 2020 (42.85%). Interestingly, we found that the majority of research in this area was conducted after the incidence of COVID-19. Among academic journals, most of the research was published in educational journals.

Second, forest education using reality technology elicited both cognitive and affective effects (71.4% cognitive effect, 63% affective effect) compared with that of education without reality technology. Compared with traditional teaching methods, forest education using reality technology was effective in motivating this intervention in the affective domain.

Third, even when forest education using reality technology was conducted indoors, the effect was significantly high both cognitively and definitively (cognitive, 90%; definition, 100%). The results show that forest education using realistic technology conducted indoors is effective. Indoor education does not experience the five senses that can be experienced in outdoor education, but it is effective in improving forest education knowledge and positively changing attitudes toward seeing the forest. When forest education using realistic technology is conducted, it has been confirmed that it can be received even in situations where it is not possible to go outdoors, and it is effective in observing phenomena that are difficult to observe outdoors. In conclusion, this study provides basic data on the current status and effectiveness of forest education using realistic technology.

Future research on reality technology and forest education could reveal various accurate analyses that could be pivotal for driving and implementing policy decisions in this field. In the future, based on the contents presented in this study, it will be necessary to conduct and measure the effectiveness of forest education using realistic technology in the field.

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