

Development of a Mobile Application, “Wild Flowers of Bukhansan National Park (version 1.0)”, for Identification of Plants in Bukhansan National Park

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Abstract: We developed the educational purpose mobile application, named “Wild Flowers of Bukhansan National Park (version 1.0)”, aiming for easy identification of wildflowers for students and visitors in the park. When visitors find a flower or part of plant in the park, visitors can search for its name utilizing the pictures and characters provided in their own smartphone mobile devices or tablet PCs. The application provides pictures of wildflowers in the park and character-based searching system based on 12 diagnostic features (e.g., growth form, leaf arrangement, flower symmetry, petal color, petal number, sepal number, etc). We adopted the complete floristic survey of Chung and Lee (1962) and added species that we confirmed their distribution in the park during the development of this application. In summary, number of vascular plants in this park was estimated to be 428 taxa including 100 families, 280 genera, 327 species, 1 subspecies, 50 varieties, and 5 formas. We provided a total of 588 pictures representing 358 taxa and each taxon includes multiple pictures in many cases. Included identification quizzes can be an efficient educational tool as well as fun activity for students and visitors who are learning plant species in Korea. Our next step will include GPS function in the application for indicating visitor's location and for providing previously reported sites of the species that we interested in the map of the park. The future application which includes GPS function will be a valuable tool for the monitoring of rare plants, plant researches related to the climate changes, etc. We currently provide Korean iPhone version only, and English version and both of android versions will be serviced soon.

Keywords: Bukhansan National Park; flora; interactive key; mobile application; wild flowers

Introduction

In Korea, the most widely utilized plant identification manuals for teaching college level taxonomy and field botany classes and for conducting various systematic and ecological researches are heavy books such as “Illustrated Flora of Korea” (Lee, 1985; 1,037 pages with approximate weight of 1.8 kg) and “Standard Illustrations of Korean Plants” (Lee, 1996; 1,032 pages with approximate weight of 2.7 kg). Quite frequently students and researchers have

to carry such heavy and bulky manuals in the field for immediate identification of plant species. However, mobile devices, such as smart phones and table PCs, are capable of replacing traditional heavy and bulky manuals and field books. In addition, mobile digital devices can provide several useful functions that traditional paper based documents could not provide.

If we search for available applications using “Ya-Sang-Hwa” or “Deul-Kkot” (which means “wild flower” in Korean) as key words for plant identification purpose, we may find few applications to date, such as the “Wild Plants of Korea” (한국의 야생식물; Asan Medical Center; App Store), “100 Wild Flowers” (우리 들꽃 100; Jongwon Woo;

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App Store; Korean name), “Wild Flower Search” (야생 화 찾기; dalcom.us@gmail.com; Android Market) and “Plant Name Search” (식물 이름 찾기; igsoftkorea@gmail.com; Android Market). However, these applications were targeted for children and general public, only delivering basic information about wildflowers, and also they have narrow application utilities due to limited number of plant species that they covered.

The “Wild Flowers of Bukhansan National Park (version 1.0)” was for the first time developed targeting for middle school, high school and college students as well as amateur naturalists/botanists who are interested in identifying wild flowers while they visit the Bukhansan National Park. This application represents the first mobile application encompassing about 85% the vascular plant species in the Bukhansan National Park and it will be a prototype for mobile research tool for researchers involved in the studies of taxonomy, ecology, conservation, etc. This application is comprised of nine parts: “Introduction”, “Park Map”, “Plant Images”, “Search by Name”, “Search by Characters”, “Classification System”, “Terminology”, “Dichotomous Keys” and “Quiz” (Fig. 1; Table 1). This paper describes the contents and functions of the application and discusses its application and future developmental plans and directions.

Materials and Methods

Based on the initial floristic study by Chung and Lee (1962) which listed 428 vascular plant taxa (372 species, 1 subspecies, 50 varieties, and 5 formas), we conducted several field works to confirm the listed plant species distributed in the Bukhansan National Park. During the course of field works, we photographed different parts of plants for the majority of species. Of the 428 listed taxa, we were able to obtain and prepare a total of 558 photographs representing 358 taxa (approximately 85% taxa coverage from the original list). The original complete list of 428 taxa by Chung and Lee (1962) is used for two search options (i.e., “Search by Name” and “Search by Characters”) as well as in “Classification Systems” and “Dichotomous Keys”. The characters used for the “Search by Characters” menu were collected based on information in the “Illustrated Flora of Korea” (Lee, 1996) and in the “Standard Illustrations of Korean Plants” (Lee, 1996) and listed up using EXCEL (Microsoft Inc., USA). The application was created using XCODE (ver. 4; Apple Inc., USA), an application development tool of the iPhone.

Table 1. Main menu of “Wild Flowers of Bukhansan National Park”, a mobile application

Menu	Function
Introduction - Park overview - Flora of the Bukhansan National Park	Brief introduction to the park: geology, history, plants and animals, and etc.
Park Map	Detailed map of hiking trails: enlargement of specified area is possible.
Plant Images	Random plant images are provided with family name (Korean and English), common name, and scientific name.
Search by Names - Common name (Korean) - Scientific name - Genus name - Family name (Korean) - Family name	Alphabetical lists of common name, scientific name, genus name, and family name are provided. Direct search with typing a name is also possible.
Search by Characters - Major category - Habit - Leaf arrangement - Leaf shape - Flower symmetry - Sepal number - Petal number - Stamen number - Special stamen types - Ovary position - Flowering time	Users may search candidate plants with observed characters in the plants that they found in the park (interactive key with 12 characters).
Classification Systems - APG system - Cronquist system	Users may search plants in the lists of families which are based on two different classification systems of angiosperms.
Terminology	Definition of each botanical term is provided as well as its Chinese and English characters.
Dichotomous Keys	Various levels (family, genus, and species) of traditional plant identification keys are provided.
Quiz	Various forms of plant-identification quizzes included in the application could be an efficient educational tool as well as a favorite game to the users.

Results

The basic function of each menu provided by the application is shown in Table 1. The main screen presents nine individual icons which are scrollable (Fig. 1), and all screens which have been directed from the nine individual icons have a "previous" button in upper left corner allowing users to go back to the main screen. The components and characteristics of the individual menus are as follows.

Introduction

This menu includes introductory information on the Bukhansan National Park and its flora. The sub-menu "Park overview" includes brief basic information about the national park (i.e., size, location, political district, geography, history and important historical sites or monuments; Box 1). In terms of the flora within the boundary of the park, the sub-menu "Flora of the Bukhansan National Park" (Box 2) provides various information such as a research project conducted in the park, representative plant species that can be observed during each season, and rare species in the park. Some species mentioned in this sub-menu with available photographs are marked in underline and further cross-linked with relevant photos (Fig. 2). Below the information provided by the sub-menus "Park overview"



Fig. 1. A main page of a mobile application, "Wild Flowers of Bukhansan National Park".

and the "Flora of the Bukhansan National Park" are displayed in Boxes 1 and 2, respectively.

Box 1. Park overview

The Bukhansan National Park, located just northern outskirts of Seoul, is the 15th national park, designated on April 2nd of 1983 with a total area of 80.669 km², and includes two major mountains Bukhansan (Mt.) and Dobongsan (Mt.). The park stretches over several political districts of Seoul, such as Dobong-gu, Gangbuk-gu, Seongbuk-gu, Jongno-gu, Seodaemun-gu and Eunpyeong-gu to its east and south, and over several cities of Gyeonggi Province, such as Goyang, Yangju and Euijeongbu to its north and west.

Bukhansan (Mt.) is the highest mountain in the area surrounding Seoul and is not clearly connected to any other major mountains of the Korean Peninsula. It used to be called Bu-a-ak (負兒嶽), Hwasan (華山), Hansan (漢山), and has also been called the Triangle Mountain, as its range encompasses three peaks, with Insubong (811 m) to the east and Mangyeongdae (800 m) to the south of the main peak of Bakundae. It is speculated that Bukhansan (Mt.) was named after the Bukhansanseong (Bukhansan Fortress) was constructed during King Jungjong of the Choseon Dynasty.

Bukhansan National Park is a beautiful natural park situated in a highly developed urban area, which is rare in other major cities around the world. It is a place for exploring well-preserved nature and acts as a "green lung" to the surrounding urban areas, attracting and serving more than 20 million Seoul residents. The park is easily accessible within the city of Seoul via various public transportations and therefore attracts approximately ten million visitors annually, placing it as "the most visited national park by visitors per surface area" in the Guinness Book of World Records.

Mangyeongdae is called Gukmangbong, as it was climbed by the Great Priest Muhak choosing the seat of government of Joseon. The monuments commemorating King Jinheung's tour in Silla Dynasty is erected in Bibong. A sheer vertical cliff of Insubong is the most renowned place for rock-climbers, and other noticeable peaks include Nojeokbong, Bohyeonbong, Munsubong and Wonhyobong. Along the valley connecting Wonhyobong and Nahanbong of the northwestern part of the National Park, the Bukhansanseong (Bukhansan Fortress) was constructed in 1711 (the 37th year of the reign of King Sukjong), including several gates such as Daedongmun, Daeseomun, Daenamun, Daeseongmun and Bogukmun.

The Bukhansan National Park is comprised of tens of clean and clear water flowing through the valleys between main rock peaks created from giant granite, creating a beautiful juxtaposition of mountain and water, and provides habitat of 1,300 species of plants and animals.

Box 2. Flora of the Bukhansan National Park

The Korean Peninsula is divided into six floristic regions and Bukhansan (Mt.) is a part of the central subregion. The central subregion shows the highest endemism among the six subregions. The composition of Bukhansan (Mt.) flora is unique in a way that both southern and northern element plants take very low percentages of the entire flora. Such characteristic makes Bukhansan (Mt.) quite unique, in that Geumgangsan (Mt.) and Seolaksan (Mt.) of the same central subregion display high levels of northern limit plants stretching over the southern boundary line. Bukhansan (Mt.) displays almost no southern element plants, with a very low level of northern plants, creating distinct central subregion traits.

The native plants of the Bukhansan National Park were initially surveyed by Chung and Lee (1962). During the course of this study conducted by the Haeun Plant Research Group, we reported a total of 428 taxa including 100 families, 280 genera, 372 species, 1 subspecies, 50 varieties and 5 formas. However, such figures are significantly different when compared to the 635 taxa of 546 species, 1 subspecies, 78 varieties and 10 formas surveyed by the National Park Management Center in 2010. Therefore, it is urgent to reinvestigate the flora of Bukhansan (Mt.) based on verified photographs and herbarium specimens.

Seasonal flora

1) Spring Flowers of the Bukhansan National Park

After a long cold winter, the presence of two species, *Alnus sibirica* Fisch. ex Turcz. (물오리나무) and *Corylus heterophylla* var. *thunbergii* Bl. (개암나무), is a harbinger of spring in Bukhansan (Mt.). The valleys and northern slope of the mountain are covered by *Hepatica asiatica* Nakai (노루귀), followed by spectacular blooming of *Viola orientalis* (Maxim.) W. Becker (노랑제비꽃) and *Lindera obtusiloba* Bl. (생강나무) in yellow color toward the middle of spring. Bukhansan (Mt.) is home of various violet plants such as *Viola orientalis* (Maxim.) W. Becker (노랑제비꽃), *Viola albida* var. *chaerophylloides* (Regel) F. Maek. (남산제비꽃), *Violarossii* Hemsl. (고깔제비꽃), *Viola variegata* Fisch. ex Link (알록제비꽃) and *Viola seoulensis* Nakai (서울제비꽃). In April, light plum-colored *Heloniopsis koreana* Fuse & al. (처녀치마) and red-brown *Asarum heterotropoides* var. *seoulense* (Nakai) Kitag. (서울족도리풀), distinct species of Bukhansan (Mt.) and Korean endemics, can be encountered in the valleys. Furthermore, *Rhododendron mucronulatum* Turcz. (진달래), *Rhododendron schlippenbachii* Max. (철쭉), *Disporum smilacinum* A. Gray (애기나리), *Pseudostellaria palibiniana* (Takeda) Ohwi (큰개별꽃), *Corydalis speciosa* Max. (산괴불주머니), *Quercus mongolica* Fisch. (신갈나무), and *Sorbus alnifolia* (S. et Z.) K. Koch. (팔배나무) can easily be spotted in the area. Lastly, beautiful white-flowered *Aceriphyllum rossii* Engl. (돌단풍) can be found in rocky crevices of the valleys.

2) Summer Flowers of the Bukhansan National Park

During the summer, Bukhansan (Mt.) begins to show higher levels of dark green vegetation, and yellow *Patrinia saniculifolia* Hemsl. (금마타리), a Korean endemic, start to blooming in high elevation of forest and rock crevices. Furthermore, purple *Indigofera kirilowii* Max. (땅비싸리) and white *Lysimachia clethroides* Duby (큰까치수염) begin to flower near the ground surface. Several species such as, *Clerodendron trichotomum* Thunb. (누리장나무), *Magnolia sieboldii* K. Koch (함박꽃나무), *Cornus kousa* Buer. (산딸나무), and *Cornus controversa* Hemsl. (층층나무) can be spotted in the forest as well.

3) Autumn Flowers of the Bukhansan National Park

Bukhansan (Mt.) displays a fantastic red hue during the autumn season with its autumn leaves, and the season is characterized by a high level of the red colored *Elsholtzia splendens* Nakai (꽃향유) near the ground. *Thalictrum uchiyamae* Nakai (자주평의다리) bloom in rock crevices near the summit of mountain and the *Allium thunbergii* G. Don (산부추) and *Aconitum jaluense* Kom. (투구꽃) can be found in mountains on rare occasions. Furthermore, the purple fruits of *Callicarpa japonica* Thunb. (작살나무) and royal blue-colored fruits of the *Clerodendron trichotomum* Thunb. (누리장나무) are spectacular attracting park visitors.

Southern and Northern element plants

Southern element plants refer to plants that thrive in the warm temperature regions of the south, and no southern element plants [e.g., *Trachelospermum asiaticum* (Siebold & Zucc.) Nakai (마삭줄), *Paederia scandens* (Lour.) Merr. (계요등), and *Arisaema ringens* Schott (큰천남성)]; these species can be found sporadically in the central Korean

Peninsula] can be observed in Bukhansan (Mt.). Northern element plants refer to plants found in the cold regions of the north and include species such as *Acer komarovii* Pojark. (시닥나무), *Patrinia saniculifolia* Hemsl. (금마타리), *Aceriphyllum rossii* Engl. (돌단풍), *Clematis heracleifolia* DC. (병조희꽃), *Salvia chanryonica* Nakai (참배암차즈기), and *Saussurea calcicola* Nakai (사창분취), which are found stretched over high mountains, such as the Taebaek Mountains.

Special Plants of the Bukhansan National Park

1) Natural Monument Species and Flagship Species

There are no natural monument species in the Bukhansan National Park. Flagship species refer to wild plants and species which signify and reflect a specific region's ecological, geographical and cultural characteristics, and such species of Bukhansan (Mt.) is designated as *Forsythia saxatilis* (Nakai) Nakai (산개나리), which includes the original species *F. saxatilis* and two recently described varieties, *F. saxatilis* var. *lanceolata* S. Lee (긴산개나리) and *F. saxatilis* var. *pilosa* S. Lee (털산개나리). The original species of *F. saxatilis* which has oval-shaped leaves and gold-white flowers is no longer found in Bukhansan (Mt.), and only *Forsythia saxatilis* var. *lanceolata* S. Lee (긴산개나리), with elliptical or lanceolate leaves with gold-white flowers, and *Forsythia saxatilis* var. *pilosa* S. Lee (털산개나리), characterized by hairs on the lower surface of leaves and gold colored flowers, can be found in the area.

2) Rare or Endangered Species

Of the 8 species in Class I and 56 species in Class II categories of endangered plant species as designated by the Ministry of Environment, only one species in the Class II category, *Abeliophyllum distichum* Nakai (미선나무), is found in Bukhansan (Mt.). *Abeliophyllum distichum* Nakai (미선나무) is endemic to Korea where it has been known to be found only in the areas near Goesan (Mt.) and Jincheon of Chungcheonbuk-do. Additional location of *Abeliophyllum distichum* Nakai (미선나무) was reported in 1982 near Hyoja-ri, Sindo-eup, Goyang-si, Gyeonggi province, located to the southwestern side of Bukhansan (Mt.), and at that time, there was a debate on whether the species was naturally occurring in this area or was escaped from cultivation. In case of the rare plants, of 217 species designated by the Korea Forest Service in 1997, only six species, *Abeliophyllum distichum* Nakai (미선나무), *Forsythia saxatilis* (Nakai) Nakai (산개나리), *Patrinia saniculifolia* Hemsl. (금마타리), *Lloydia triflora* (Ledeb.) Baker (나도개감채), *Syringa velutina* var. *kamibayashii* T. Lee (정향나무), and *Viola albida* Palibin (태백제비꽃), are found in the area. Of six rare plant species, *Forsythia saxatilis* (Nakai) Nakai (산개나리) is found in very low numbers exclusively in Bukhansan (Mt.) out of the entire Korean Peninsula. Therefore, the species must soon be protected by the government after being included in the list of Endangered Species as designated by the Ministry of Environment.

3) Korean Endemic Plants

Korean endemics are plant species that only occur in Korea and they are well adapted to the natural environment of the Korean Peninsula. Such species of Bukhansan (Mt.) include the *Forsythia saxatilis* (Nakai) Nakai (산개나리), *Patrinia saniculifolia* Hemsl. (금마타리), *Asarum mandshuricum* for. *seoulense* (Nakai) M. Kim & S. So (서울족도리풀), *Heloniopsis koreana* S. Fuse (처녀치마), *Viola seoulensis* Nakai (서울제비꽃), *Cirsium setidens* (Dunn) Nakai (고려엉겅퀴), *Lilium amabile* Palibin (털중나리), *Salvia chanryonica* Nakai (참배암차즈기), *Saussurea calcicola* Nakai (사창분취), *Weigela subsessilis* L.H.Bailey (병꽃나무), and *Paulownia coreana* Uyeki (오동나무).

Naturalized Plants of the Bukhansan National Park

Naturalized plants are introduced plants from other countries and they reproduce spontaneously. Since naturalized plants are known to well adapt to less favorable environments with high reproductive output, they quite often outcompete some native species. Naturalized plants found in Bukhansan (Mt.) include *Alnus firma* S. et Z. (사방오리나무), *Robinia pseudoacacia* L. (아까시나무), *Pterocarya stenoptera* DC. (중국굴피나무), *Ambrosia artemisiifolia* L. (돼지풀), *Ambrosia trifida* L. (단풍잎돼지풀), *Aster subulatus* Michx. (비자루국화), *Erechtites hieracifolia* Raf. (붉은서나물), and *Erigeron annuus* (L.) Pers. (개망초), alongside *Castanea crenata* S. et Z. (밤나무) and *Saxifraga stolonifera* Meerb. (바위취).

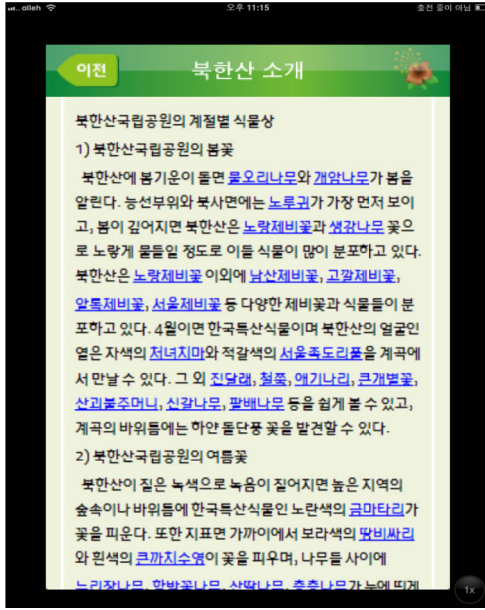


Fig. 2. "Introduction" page. Plant names in the text are linked to their images.

2) Park Map

A trailer's map which can be zoomed in was provided to assist visitors observing wild flowers (Fig. 3). The map scale is in 1:35,000 published by the Bukhansan National Park (January 1st of 2007), with hiking trails marked in detail. While the current version only includes zoom-in function, future upgraded versions are expected to mark the current location of users using a GPS.

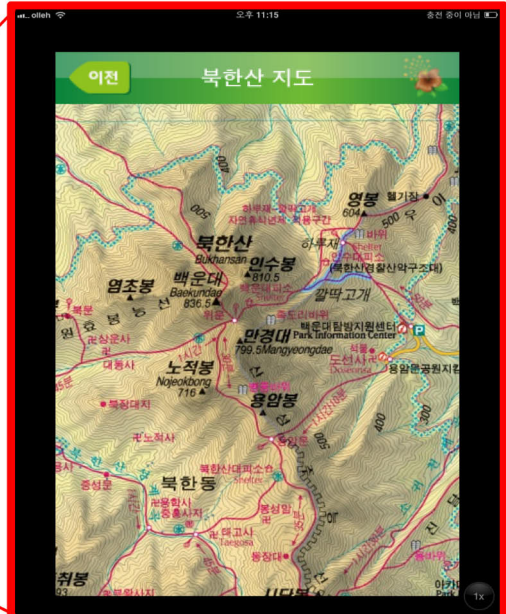
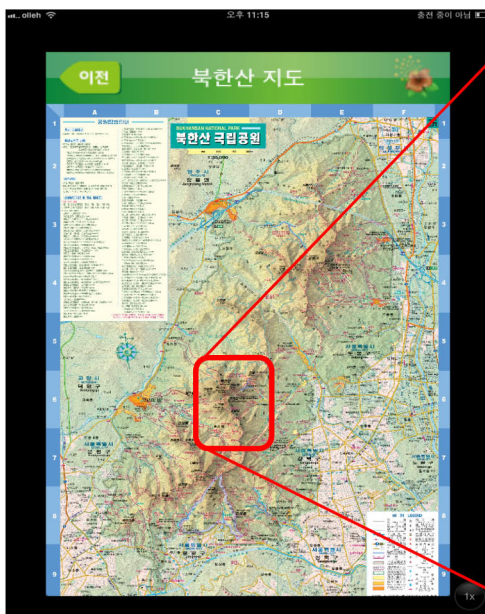


Fig. 3. Detailed visitor's map of Bukhansan National Park (1:35,000 scale) is included in the application. Enlargement of specified area is possible.

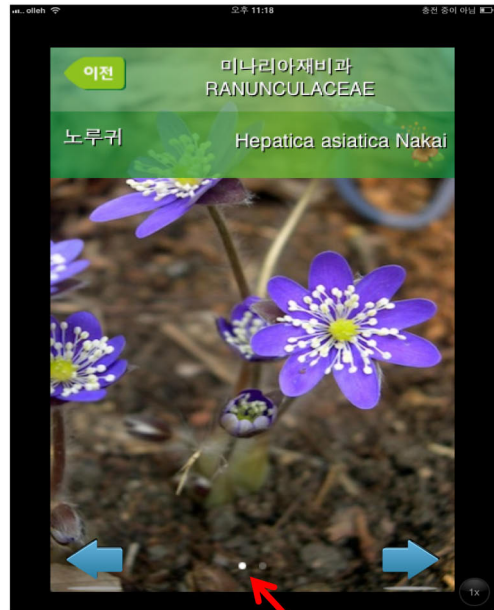


Fig. 4. A format of each plant item includes family name, common name, and scientific name. Arrows in the left and right side of bottom are linked to the images of related taxa. If multiple images are present for a taxon, multiple dots are indicated at the bottom (arrow).

3) Plant Images

The menu includes photos, as well as both the common and scientific names (Korean and English) of the individual species (Fig. 4). The "Observation" menu shows the photo of a random plant, and the arrows located at the bottom of the screen are touch activated to navigate through the plants

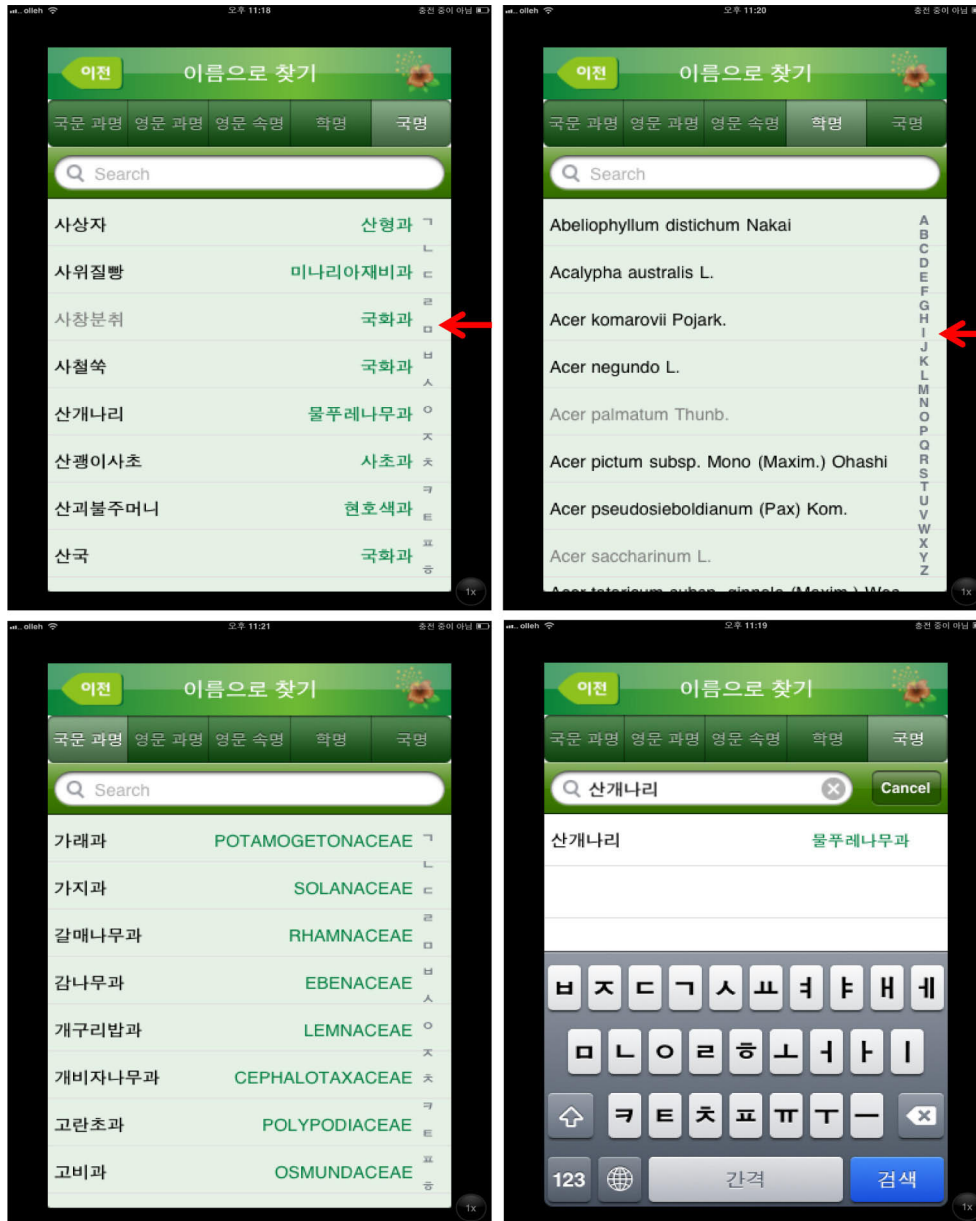


Fig. 5. "Search by Names" provide alphabetical lists of common name, scientific name, genus name, and family name. Jump access to each alphabet (arrows) and direct search with typing a name are also possible.

which have been organized via the Cronquist (1981) System. If available, multiple photographs showing different parts of plant or different plants of each taxon are provided in order to make identification easier: multiple photographed taxon is marked by the several dots at the bottom of the screen (Fig. 4 red arrows), allowing users to slide through other photos of the taxon.

4) Search by Names

The "Search by Names" menu provides several search options via common name, scientific name, English family name, and Korean family name, and users can browse through via Korean or English names in alphabetical orders

(i.e., 가, 나, 다... or A, B, C...) on the right side of the screen (Fig. 5 red arrows). In the list provided, the common name in Korean is simultaneously displayed with its family name in Korean and the English genus name with its family name in English. In addition, English family name displays simultaneously with Korean family name and vice versa. Touch activating the search result directs the users to the plant photo from the Korean common and scientific names, and complete list of taxa under each family and genus is also provided. The users can also perform direct search, directly entering either Korean common name or scientific name, using the "Search" icon located in upper part of the screen. Search results of plant names are linked to photos of

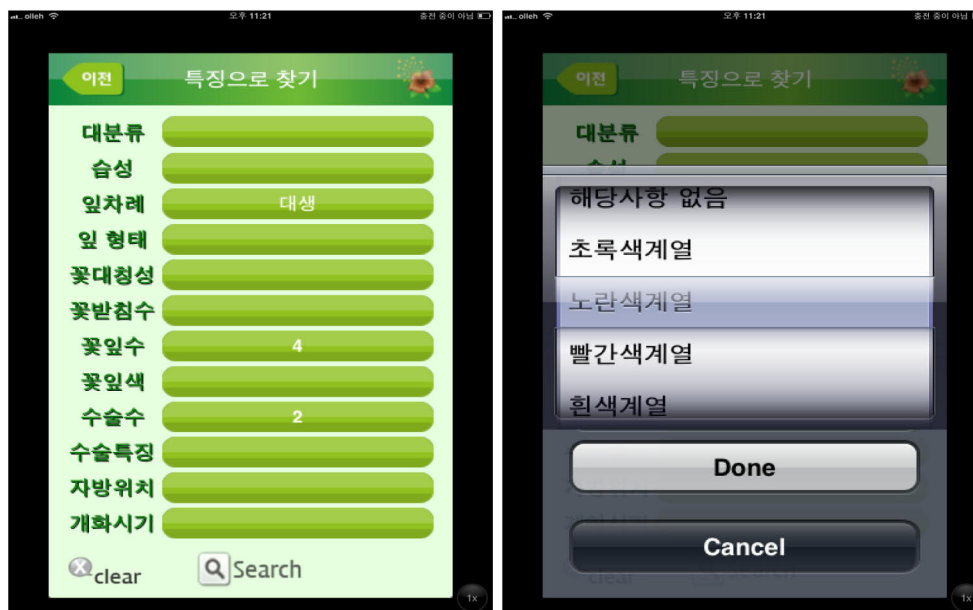


Fig. 6. “Search by Characters” provide the filtering of taxa with character states of twelve major diagnostic characters.

the individual plants, and display methods are the same as the “Observation” menu.

5) Search by Characters

The “Search by Characters” menu allows users to search plants via combinations of several features which can be easily observed (Fig. 6). Such physical traits are divided into 12 categories, including main classification (Pteridophytes/Gymnosperms/Dicots/Monocots), habit or growth form (tree/shrub/herb), leaf arrangement (alternate/opposite/whorled), leaf form (simple/trifoliolate/pinnately compound/palmately compound), flower symmetry (bilateral/radial), calyx number (1/2/3/4/5/6/7/8/9/), petal number (1/2/3/4/5/6/7/8/9/), flower color (green/yellow/red/white/blue), stamen number (1/2/3/4/5/6/7/8/9/10/11/12/), stamen trait (didynamous/tetradynamous/diadelphous/syngonous), ovary position (superior/half inferior/inferior) and flowering time (1/2/3/4/5/6/7/8/9/10/11/12). Users can select as many available and observable characteristics as they could find and hit the “search” button to narrow down to the list of probable taxa. If certain features could not be applied for some taxa (i.e., NA: not applicable), then they were removed from search results. For example, when users apply “flower symmetry” category, all Pteridophytes were excluded. If data on certain features are not available (i.e., ND: no data), they were included in the research results. For example, if the exact flowering time of certain taxon is not coded, the original data will be “ND” and the research results with certain month will include this taxon. With regard to the “flower symmetry” category, this term could be difficult to apply for the members of family Asteraceae (Sunflower family); for example, a single

flower appearance of sunflower is actually the clusters of ray (strapped shaped and peripheral) and disk (tubular and central) flowers on expanded flattened receptacle, constituting the inflorescence (arrangement of flowers) type of head or capitulum (Judd *et al.*, 2009). This could give some confusion between professional botanists and nonspecialists. Therefore, in order to avoid such confusion, we consistently used the radial symmetry as flower symmetry for the members of Asteraceae based on their general superficial appearance of single flower in radial symmetry. Additional explanation when select the “flower symmetry” was given in the screen.

6) Classification Systems

The “classification” menu provides a list of families within each category to show taxonomic position of plant species in Bukhansan National Park in the most widely used and accepted classification system (Fig. 7). Based on the list of families, users can scroll down to find the list of genera within each family that could be found in Bukhansan National Park. Additional photo links are provided after clicking each taxon.

For Pteridophytes, we adopted the most comprehensive and widely accepted molecular phylogenetic system by Pryer (2001). With regard to the angiosperms (flowering plants), we adopted both the most contemporary phylogeny-based APG (Angiosperm Phylogeny Group) classification system (Haston *et al.*, 2007) and one of widely accepted traditional classification system of Cronquist (1981).

7) Terminology

The “Terminology” provides unfamiliar botanical/taxonomic

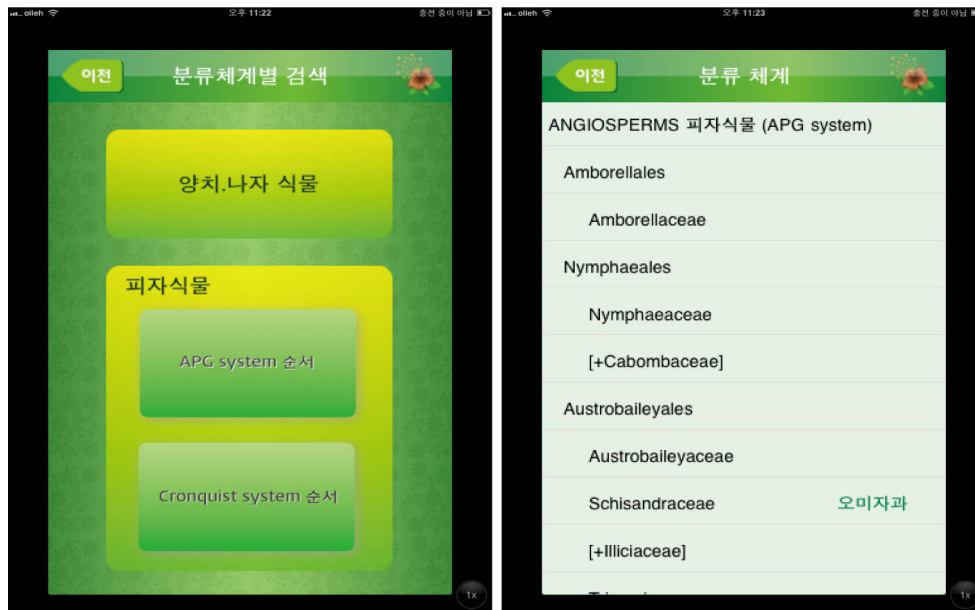


Fig. 7. Main page of "Classification Systems" and a capture image of a part of family list of the Angiosperm Phylogeny Group system (Haston et al., 2007).

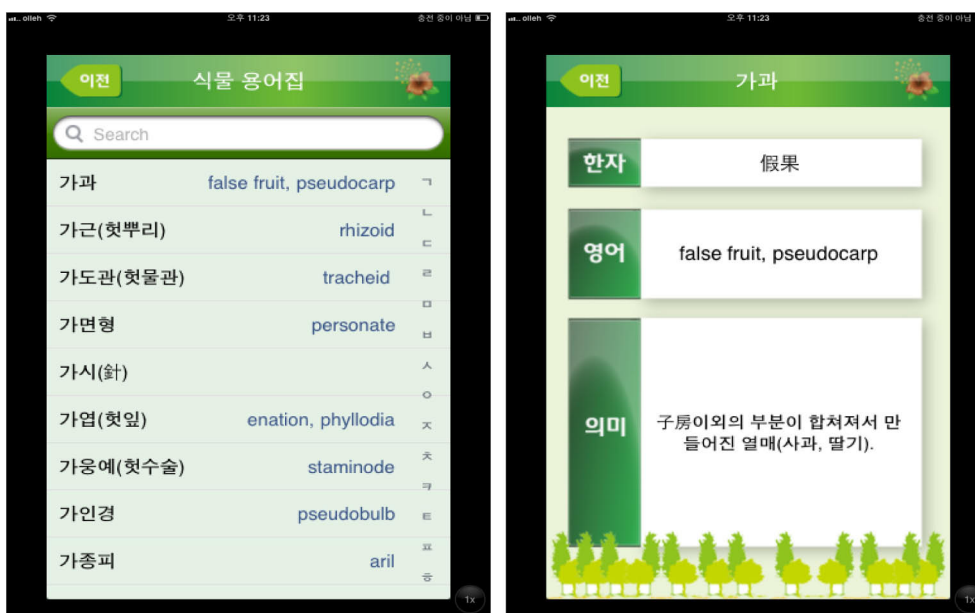


Fig. 8. "Terminology" provides the meaning of botanical terminologies as well as Chinese and English characters of each term.

terms in Chinese and English with easy and brief Korean explanation for each term to students and nonspecialists (Fig. 8). We modified the terminology from "Dichotomous Keys of the Korean Plants" (Lee, 1997), with the special permission from the author.

8) Dichotomous Keys

The menu "Dichotomous Keys" provides hyperlinks for identification of each of the 428 taxa found in the Bukhansan National Park. The Dichotomous keys provided in this menu were created and modified by extracting

information about the 428 taxa from the original dichotomous keys of the Korean flora (Lee, 1997). The main screen of the "Dichotomous Keys" displays main classification (Pteridophytes/Gymnosperms/Monocots/Dicots), and the list of families is provided for each category. Within each family and genus, the list of genera and species is also provided, respectively. This information utilized the hyperlink method in order to make user friendly (Fig. 9). This function incorporated the web view method connected to the server, since using hyperlinks is highly complicated in terms of mobile application programming.

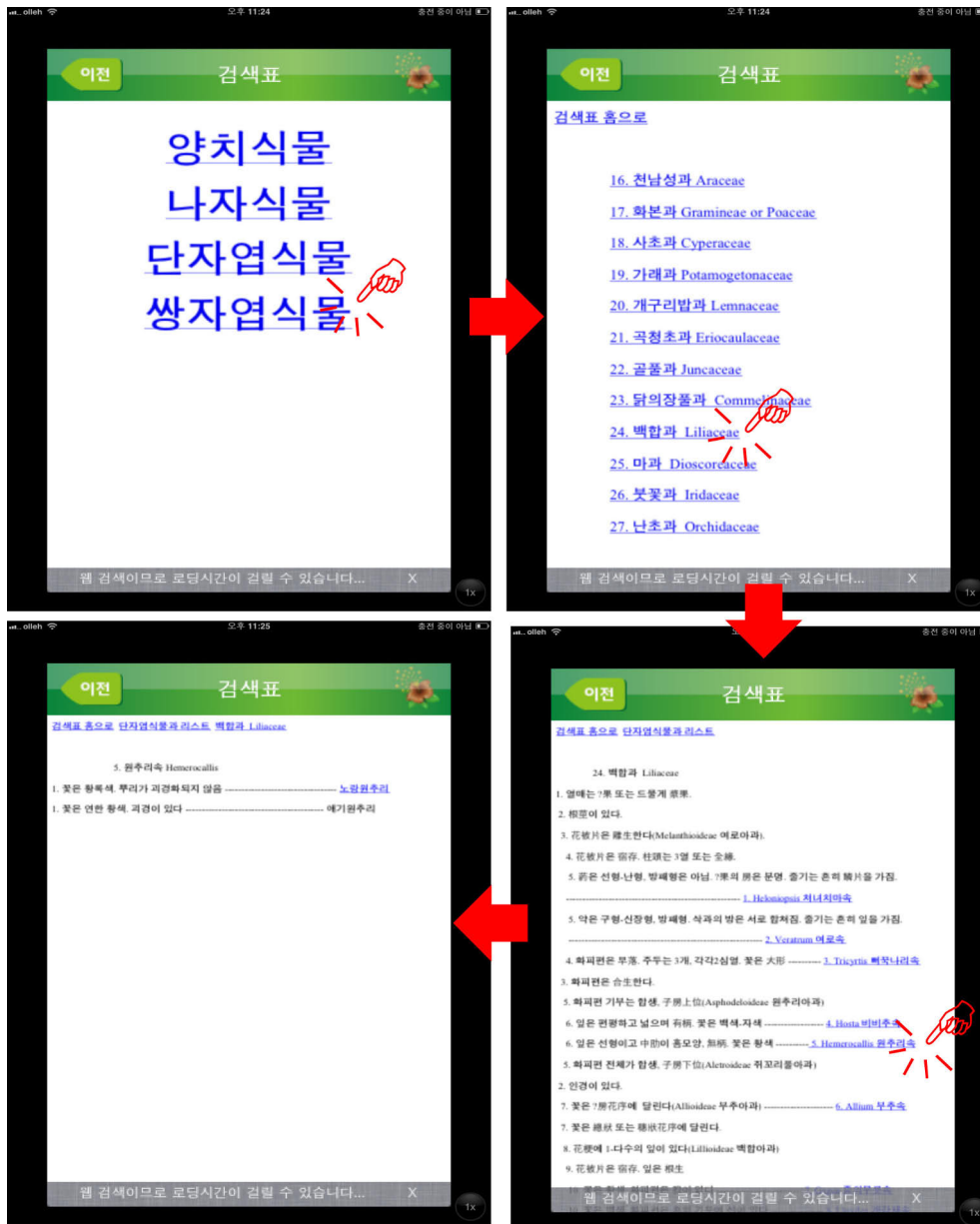


Fig. 9. Hierarchical structure of “Dichotomous Keys” for plants in the Bukhansan National Park. Hyperlinks connect keys of each level.

9) Quiz

Lastly, the quiz menu was also added to stimulate student’s and general public’s interests on wildflowers. This could also enhance learning process of college students who take plant taxonomy class as well as amateur botanists. For beginners, Korean common names and their Korean family names are questioned. For intermediate level users, English genus names and English family names are quizzed. Lastly, for advanced users, scientific names were tested. For each level, ten multiple choice questions are provided. When the wrong answer is selected, the user must continue to choose other answer until the correct answer is selected. Such method was developed in order to improve the application's role in learning process.

Discussion

The advancements in database using computers have organized tremendous amount of data previously stored in paper based books and have made searching tools easier. Currently, mobile technologies and tools have revolutionized the use of those available data and information during field studies related to biological research, especially plant taxonomy and ecology. The application that we developed in this study presents the possibilities of utilizing mobile devices in the field oriented research. Currently, the application is aimed at students and visitors in Bukhansan National Park, but the future addition of various functions will allow the applications to become more powerful tools, in which can



Fig. 10. Various forms of plant-identification quizzes are included in the application.

also be applicable for professional research. One such example includes utilizing the GPS function of smartphones to indicate the previously reported sites of target plants on the map and to perform mass-collection of new data. This will be used for the monitoring of endangered and ecologically important species by professional researchers. We anticipate that this kind of valuable information could be used to study climatic change and strategic development responding to predicted changes in the flora of Bukhansan National Park.

Perhaps the best and easiest method of plant identification is replacing cumbersome process of using dichotomous keys by image recognition-based automated identification. One such exemplary application is called "Leafsnap" (Peter

Belhumeur; App Store). This application provides various photos of plants found primarily in the northeast region of the United States, and taking a snapshot of a plant outdoors will analyze and determine the plant species. Currently, recognition via only leaves is possible, and instead of providing automated precise identification of plant species, this application narrows down to the list of possible candidate taxa due to highly variable nature of leaf characters. We hope to incorporate image based identification tool for the "Wild Flowers of Bukhansan" application in the future and thus both general public and professional researchers could fully utilize such easy and accurate plant identification tool.

One of the most significant advantages of a mobile

application over print documents is that continuous updates are able to correct any errors or to incorporate easily new additional information. This application contains the link of the creators so that users are able to report any errors or bugs, so that periodic upgrades can be provided. Currently, the “Wild Flowers of Bukhansan” application is available on the iPhone only and is currently under development for the Android and English version.

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