

Assessment of mobile phone applications feasibility on plant recognition: comparison with Google Lens AR-app

Zhanna I. Bilyk¹[0000-0002-2092-5241], Yevhenii B. Shapovalov¹[0000-0003-3732-9486],
Viktor B. Shapovalov¹[0000-0001-6315-649X], Anna P. Megalinska²[0000-0001-8662-8584],
Fabian Andruszkiewicz³[0000-0001-5318-3793] and
Agnieszka Dołhańczuk-Śródka³[0000-0002-9654-4111]

¹ National Center “Junior Academy of Sciences of Ukraine”,
38/44 Dehtiarivska Str., Kyiv, 04119, Ukraine

² National Dragomanov Pedagogical University, 9, Pyrogova Str., Kyiv, 01601, Ukraine

³ Uniwersytet Opolski, 11a Kopernika pl., Opole, 45-040, Poland
zhanna_bio@man.gov.ua

Abstract. The paper is devoted to systemizing all mobile applications used during the STEM-classes and can be used to identify plants. There are 10 mobile applications that are plant identifiers worldwide. These applications can be divided into three groups, such as plant identifiers that can analyze photos, plant classification provides the possibility to identify plants manually, plants-care apps that remind water of the plant, or change the soil. In this work, mobile apps such as Flora Incognita, PlantNet, PlantSnap, PictureThis, LeafSnap, Seek, PlantNet were analyzed for usability parameters and accuracy of identification. To provide usability analysis, a survey of experts of digital education on installation simplicity, level of friendliness of the interface, and correctness of picture processing. It is proved that Flora Incognita and PlantNet are the most usable and the most informative interface from plant identification apps. However, they were characterized by significantly lower accuracy compared to Google Lens results. Further comparison of the usability of applications that have been tested in the article with Google Lens, proves that Google Lens characterize by better usability and therefore, Google Lens is the most recommended app to use to provide plant identification during biology classes.

Keywords: mobile application, STEM-classes, augmented reality, plant identification, Google Lens.

1 Introduction

To date, the introduction of a mobile phone into the educational process is a modern instrument to achieve better results. The usage of a mobile phone during classes allows visualization of educational material, involving students in research, which increases students' motivation for learning [20; 26]. Mobile phone applications compared to computer approaches are characterized by the most promising advantages including mobility of usage, possibility to use both internal and external sensors (not commonly

used). The modern educational directions include personalization of research process which may be achieved by using mobile phones [25]. However, it was proved that not elements of education led to high efficiency but a general didactic approach during which it was used. The main concept during which the mobile approach relevant to use is STEM/STEAM/STREAM technology. It includes elements of both research and engineering which can be based on the use of computer software or mobile applications.

1.1 Types of educational software

All software that can be used during the learning process in the application of STEM technology can be divided into desktop applications, mobile applications, and web-oriented technologies. There are a lot of scientific papers related to ways of ICT implementation during STEM-based classes. The most interesting of them are providing of augmented reality [2; 21; 26; 27; 29; 30; 33; 37], virtual reality [3; 14; 16; 20; 23; 24; 31; 32; 35; 45], providing of digital environments of education, including computer modeling [7; 19; 34; 36; 40;], providing of centralized educational networks [38; 41; 43], mobile-based education [18; 22; 27; 28; 33], modeling environments [4; 8; 9; 12; 17] providing of education visualization by including YouTube videos [6], 3D modeling [5], and printing [15], etc. Comparisons of the most used in the education process software are presented in table 1.

Table 1. Comparisons of the most used in the education process software.

Type	Web-oriented	Mobile applications	Desktop applications
Installation	Not needed	From official stores or using application file	From official stores or installation files
General requirements	Compatible Internet browser for all feathers support	Compatible version of Android, iOS or another mobile operating system	Compatible version of Windows / macOS / Linux or another desktop operating system
Facilities	Modeling, calculation, visualization, video presenting	Modeling, calculation, visualization, video presenting, measuring using both internal and external sensors, photo analysis, AR, VR	Modeling, calculation, visualization, video presenting, using additional external sensors
Main advantages	Cross-platforming, no installation required, low device space usage	Huge facilities, mobility of usage	Stability, huge spreading, and variation of applications
Main disadvantages	Limited opportunities, may not start correctly depending on the platform and technical characteristics, lack of individualization	Needs technical updates which may be expensive	Lack of individualization, the lesser effect of increasing motivation during STEM-education

As shown on the table, one of the most perspective to use in education is the mobile application due to their multi-capabilities, interaction with students in their research and visualization on the educational process. Nowadays a lot of pedagogical researches is related to analyzing approaches mobile phone applications can be used during the educational process. In general, based on the facilities, it is possible to provide a classification of mobile application on those which provides measuring, analyzing, the image recognizing and its classification, providing course education, VR, and AR-based. We offer to structure training applications that can be installed on a student's mobile phone into the following categories, such as:

- training platforms;
- meter applications;
- video analysis apps;
- applications that analyze images and classify them;
- augmented reality (AR) and VR apps.

Comparisons of different mobile apps categories are shown in table 2.

Table 2. Comparisons of different mobile apps categories.

Type of application	Description	Examples
Education platforms	These platforms allow the teacher to create instructional content, communicate with students, give them assignments and check them out automatically	Google Classroom, Prometheus, Coursera, Microsoft Office 365 for Educational
Measuring applications	These sensors and their software are already built into mobile phones	Measure, AR-ruler, Smart Measure, Lux-meter, Accelerometer, Magnet Field Meter
Image analysis apps	It allows you to measure distances, angles, perimeters, areas, and calculate with this data.	ImageMeter
Image recognizing and it's classification applications	These mobile applications allow you to identify species of plants and animals using photos	Google Lens, Photo Sherlock, Plant Net Identification, Mushroom, Identify, Shazam, Dog Scanner, Identify Anything
VR and AR-based apps	Allow virtual travel, get a spatial image of the training material.	Minecraft Earth, IKEA Place, Ideofit, Lego Hidden Side

We can distinguish some smartphone apps which give the highest potential to increase motivation and integration with providing investigation, especially in biology, which is apps-identifiers. Today, there is a range of mobile applications that identify wildlife. These supplements can identify insects (for example, Insect identifier Photo), animals (Dog Scanner), and plants (Flora Incognita, PlantSnap, Picture This). Some

applications identify both plants and animals, for example, Seek. In our opinion, most perspectives are applications that provide analyzing of the static its nature objects (plants) due to the photographic process don't require highly expensive smartphones to obtain sufficient quality photography to provide analysis. Therefore, this approach can be used widely during the educational process, almost in all schools.

1.2 The problem of plants identification

There are about 27,000 species of flora in Ukraine, such biodiversity requires detailed description and study. Also, natural conditions are constantly changing, and this causes changes in the species composition of biocenosis. Both aspects indicate that there is a problem with plant identification. One of the basic principles of pedagogy is the principle of a nature experiment. So, training should be carried out in an environment where the mobile phone should become a full-fledged learning tool.

Some apps can be installed on the student's mobile phone for free to determine the species of plants, their morphology, the range of distribution, and more. In our previous research, it was found that Google Lens characterized by very high accuracy of identification, especially on trees and shrubs [39]. Taking to the account simplicity of the application and its dissemination, there some papers and devoted to describing and researching Google Lens [10; 11; 42]. Google lens can provide analysis of real-life objects in AR and provide additional information neural networks algorithms. However, other applications can be used to provide identification and these applications may be more specialized. Therefore, they can provide more accurate analysis because their database consists only of plants images which can decrease the number of false detections, and apps can provide more correct process of plant identification and inputting the information (requesting from the user to input different parts of plants).

Despite the great specialization of other applications, we hypothesize that Google Lens is the best plant analyzer due to the large selection of plants and the existence of a special application for teaching it to a large number of people – Google Crowdsourcing (500 000+ installation).

Therefore, the purpose of this article is to analyze existing applications that can be used in teaching biology both in the classroom and in the field.

There are about 10 applications that can be used to identify the plants. Most common of them are LeafSnap, Seek, PlantNet, Flora Incognita, PlantSnap, Picture This, Florist-X (in Russian), What is a flower (in Russian), Manager of houseplants (in Russian).

These applications can be divided into three groups, such as:

- plant identifiers that can analyze photos (Google Lens, for example, PlantNet, Flora Incognita, PlantSnap, Picture This.
- plant classification provides the possibility to identify plants manually. The plant's classificatory commonly contains pictures and information about plant kind. But the quality of analysis, in this case, will depend on the user's knowledge and skills which may be hard for both teachers and students. Their use in biology lessons within the STEM approach has considerable potential because it allows for interesting and rapid acquisition of plant morphology. However, it works like an interactive book

that can interact with students lesser than apps of the first type (for example, Florist-X and What is a flower).

- plants-care apps that remind water of the plant or change the soil, which by the lower potential compared to other types of application (for example Manager of houseplants).

Taking into account all advantages of plant identifiers, it was used as an object of the research. The analysis of the general view is shown below.

Flora Incognita. According to the developer, the application can identify 4800 species of plants. Before the analysis user chooses plant type (flower, tree, grass). The process of analyzing requests photographs of different plant parts. After determining the species, it links to Wikipedia and the site www.plantarium. A general view of the application interface is presented in figure 1.

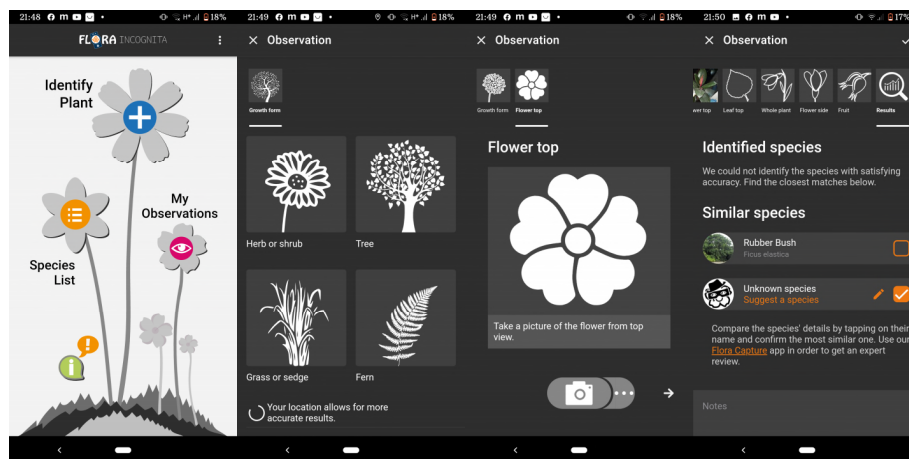


Fig. 1. Flora Incognita interface.

PlantNet. According to the developer, this application can identify 21,920 species of plants. It contains headings: flora of the world (very broad heading Western Europe, USA, Canada, Central America, Caribbean islands, Amazon, French Polynesia), useful plants, invasive plants, weeds. The user can confirm the particular plant, i.e. the program is being trained. When determining the part of the plant (root, shoot) is indicated. There are photos by family and you can determine by family, the principle is the determinant.

There is no connection with other information resources, information about the species is very limited (only photo and Latin name). A general view of the application interface is presented in figure 2.

PlantSnap. According to the developer, this application can identify 585,000 species of plants. Need to create a profile. This can be done using Facebook, almost Gmail Google. Detailed instructions come to the user's mail. It contains instructions with English voice and Russian subtitles. You get a photo and the program offers several options. You can also use images you already have in the gallery. When you

define a program, you save, that is, confirm. It contains a ribbon where each corset can post and comment. There are no links to other resources, only the photo and the Latin name of the plant. PlantSnap limits identifications by 25 plants per account per day A general view of the application interface is presented in figure 3.

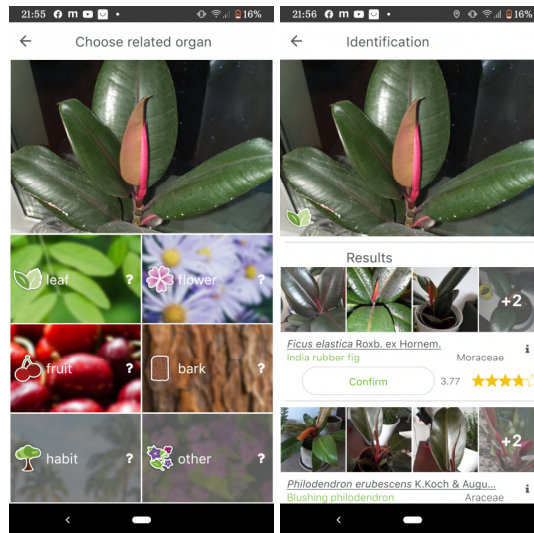


Fig. 2. PlantNet interface.

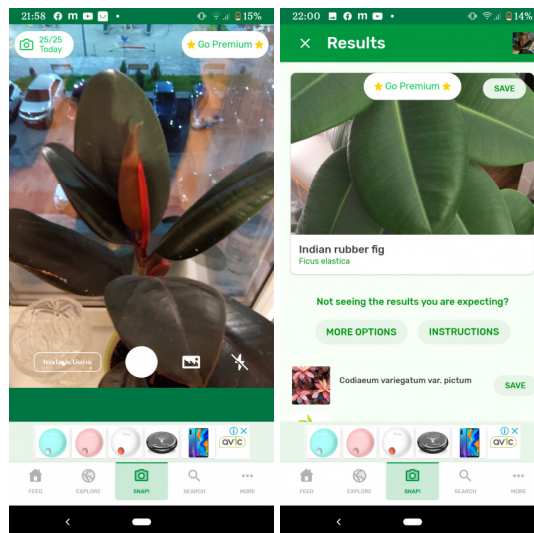


Fig. 3. PlantSnap interface.

PictureThis. According to the developer, this application can identify 10,000 species of plants. During authorization, prompts to enter a bank card immediately, if the user

does not, offers a free version. The user points the camera and the program determines the species, under the name of the species is given a botanical description, an interesting fact about the plant. There are plants that you cannot identify yourself, sent by other users, that is how the program learns. A general view of the application interface is presented in figure 4.

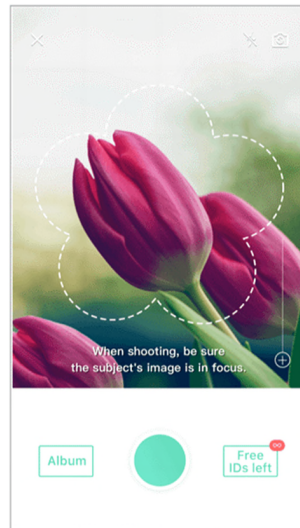


Fig. 4. PictureThis interface.

LeafSnap. The user takes a picture of the plant, indicating which part of the plant it is. And then he chooses the most similar look in the photos. The botanical description of the plant is given under the name of the species. A general view of the application interface is presented in figure 5.

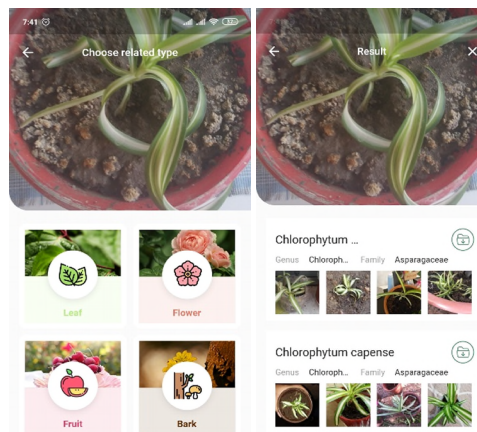


Fig. 5. LeafSnap interface.

Seek. It contains instructions, offers INATURALIST authorization, but can be operated without authorization. Immediately determines the geographical location of the user, sets the rules of safety in the wild. The mobile application provides clear, concise instructions for each stage of the study. For each activity the participant gets achieves that is motivation to learn. The app invites you to participate in nature research projects. A general view of the application interface is presented in figure 6.

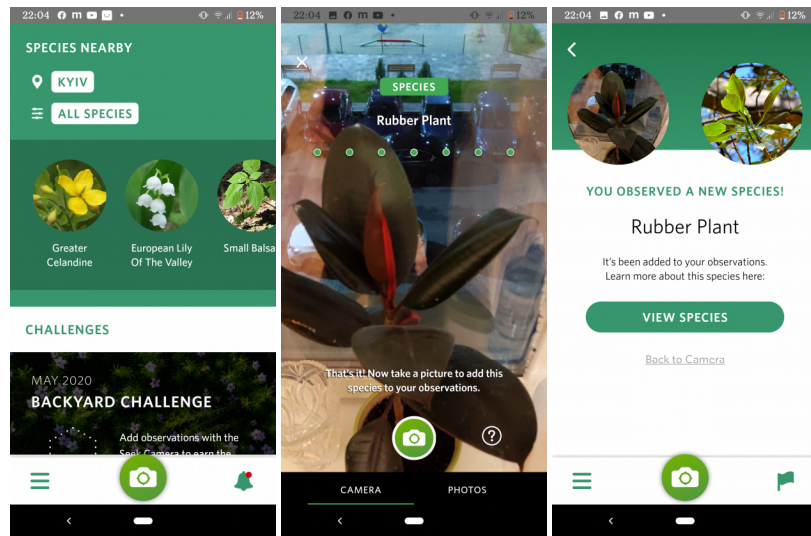


Fig. 6. Seek interface.

2 Methods of analyzing

To provide analysis on the usability of applications related to plant identification, a survey of experts on digital didactics was provided. The main criteria were installation simplicity, level of friendliness of the interface, correctness of picture processing. Each criterion was evaluated from 0 to 5 (as higher than better). Those applications which were characterized by average evaluation more than 4 were used to further analysis on quality of identification due taken to account fact usage of the application during the educational process, where it will be used by students and teachers, both potentially with not the highest level of ICT competence.

Analysis of quality of identification was provided by a simplified method compared to our previous research [34] due aim of this paper to obtain general state on application plant identification accuracy. To provide it, 350 images from the list of plants of the “Dneprovskiy district of Kiev” were taken to provide analysis. The key from the “Dneprovskiy district of Kiev” plant classification was used as control. To provide an evaluation table for each application was used. For each correctly defined type of application received 1 point (see an example in table 3).

Table 3. Example on the table of apps analyzing.

The name of the plant	Flora Incognita	PlantNet
Prunus armeniaca (Apricot)	0	0
Jasione montana	0	1
Ageratum houstonianum	0	1
Chaenomeles japonica	0	0
Amaranthus	1	0
Ambrosia artemisiifolia	0	1
Amorpha fruticosa	0	0
Anemo	1	1
Anemonoides ranunculoides	1	0
Anisanthus tectorum	0	0

Finally, all obtained results, including both, general usability evaluation (survey) and results on identification quality were compared with results on Google Lens to summarize information and achieve a general and final state in this field.

3 Results

3.1 Analysis of application identification accuracy

To compare mobile applications, it is important to explore the algorithm for identifying plants.

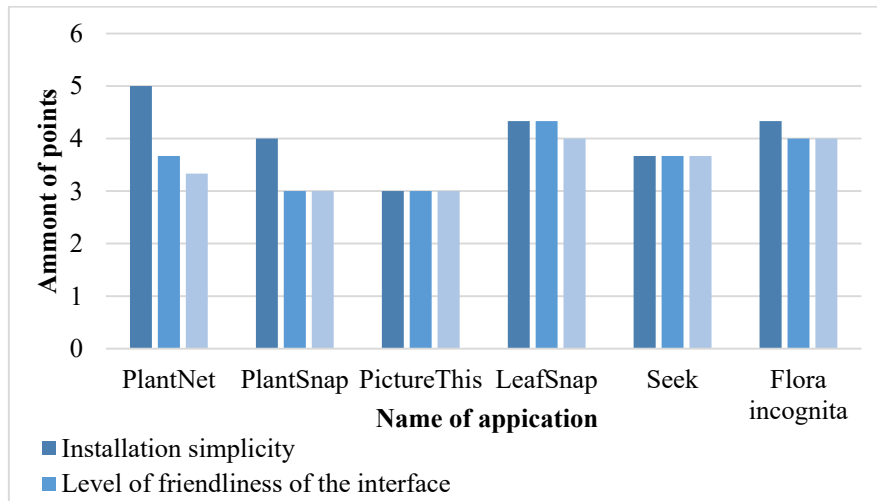
According to botanical science, the algorithm for determining a plant includes: establishing the life form of the plant (tree, bush, grass); then studying the vegetative parts of the plant (leaves, stem). Generally speaking, generative organs (flower or fruit) analysis is often required to establish a specific species name. Geographic location is very important to identify many species. For example, *Picea omorika* and *Picea abies* are very similar species, but *Picea omorika* only in Western Siberia and Eastern Bosnia and Herzegovina. If the algorithm for determining the plant in the application includes the definition of life form, photographing the vegetative and generative organs, as well as the geographical location of the object, then we consider such an algorithm completely correct. If the application of plant identification is based on photographs of different organs of the plant, such an algorithm is correct. If the application of the plant is based on the analysis of one image in one click, then this is a simple algorithm. The educational process needs to have links to other sources.

The results of comparing mobile applications that can analyze plant photos are shown in table 4.

PlantNet is the easiest app to install. Also, pretty easy to install are LeafSnap and Flora Incognita. Apps LeafSnap, Flora Incognita, and Seek to have the simplest interface. PlantSnap, PictureThis, and PlantNet are characterized by the most uncomfortable process of identification which can be complicated for teachers. Results of detailed analyses on plant identification applications are presented in figure 7.

Table 4. The results of comparing mobile applications that can analyze plant photos.

	Amount of the plants	Correctly process of analyzing	Communication with other information services
Flora Incognita	4800 (only German)	The analysis algorithm is correct	Contains links to Catalogue of Life, Plants for a Future and Wikipedia. Flora Incognita with Russian interface provides links to the Russian site www.plantarium.ru
PlantNet	21920	The analysis algorithm is completely correct	Only the name of the plant. Includes elements of social networks (by sharing plants student found and subscriptions). It contains links to Wikipedia.
PlantSnap	585000	The analysis algorithm is simple.	Own description. Provides searching on amazon to buy
PictureThis	10000	The analysis algorithm is simple.	Provides very structured information (including type, lifespan, height, flower diameter), care aspects, usage of the plant
LeafSnap	No information available	The analysis algorithm is correct. After determining, the collection of photos of this plant in different conditions (healthy and unhealthy) is possible to use.	Contains links to Wikipedia, Pl@ntUse, Global Biodiversity Information Facility
Seek	No information available	The analysis algorithm is the simplest. For identification users get archives	Has no detailed description, but propose "species nearby in this taxon"

**Fig. 7.** Results of detailed results on plants identification applications usability analysis.

In general, LeafSnap, Flora Incognita, PlanNet are the most usable. However, the total number of points each of the applications received is presented in figure 8.

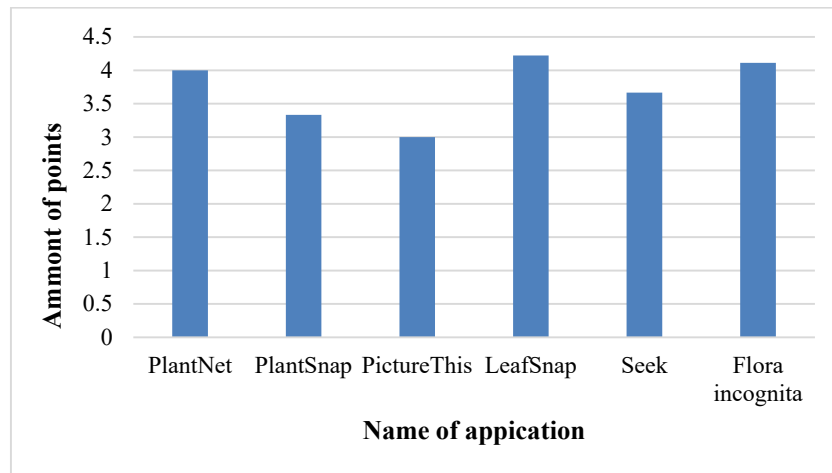


Fig. 8. Integrated results on the usability of plants identification applications.

Flora Incognita provides correct identification of 71% of plants compared to 55% provided by PlantNet. For comparison, this figure for Google Lens is 92.6%. In our previous work, we demonstrated that Google Lens does not differentiate native species from Ukraine. It seems like PlantNet provides the same Google Lens searching only in international resources, unlike Flora Incognita which provides searching at Russian web-site (in case choosing of Ukrainian region). This may explain a higher percent of identification accuracy of Flora Incognita, compared to PlantNet. The comparison of Google Lens with Flora Incognita and PlantNet identification quality is presented in figure 9.

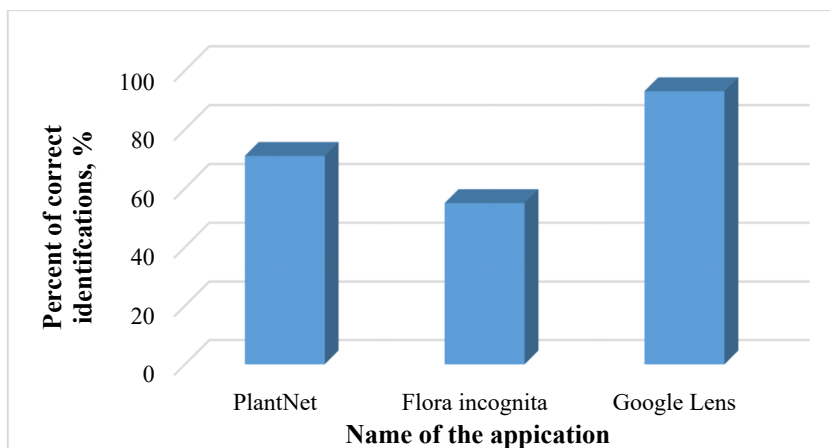


Fig. 9. Results on analysis quality of apps which is identified plant.

So, Google Lens is characterized by the highest quality of analysis which may be due to the better recognition algorithm and the most trained neural network. However, it still may be relevant to use other applications in case it will be characterized by significantly higher parameters of using. To evaluate this, a similar survey as used for other plant identification applications was used for Google Lens. Google Lens has the most intuitive interface, is the most easily loaded, and gives the most accurate definition result and therefore is characterized by the highest general evaluation. A comparison of the total points scored by the experts is presented in figure 10.

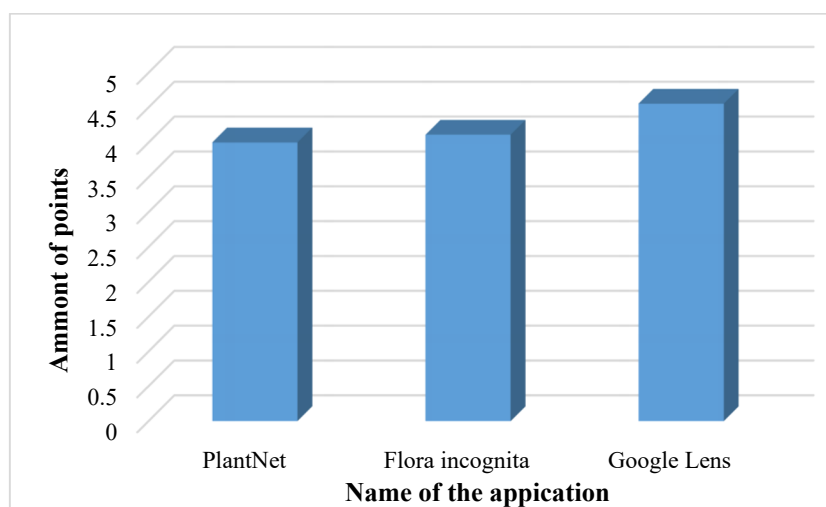


Fig. 10. Integrated results of usability level of PlantNet, Flora Incognita and Google Lens.

Therefore, Google Lens is the most recommended app to use. Talking to account, results of usability analysis, and quality of analysis, for those students and teachers who do not like Google Lens app, it is possible to use Flora Incognita, but PlantNet can't be recommended to use due low accuracy which may provide up to half of incorrect analyzing results.

3.2 Specific features of the applications to use in your own research

Despite the disadvantages, some features of depiction are worth note. Some applications have their own approach to provide complex research of nature. Those features are very useful to increase the motivation of students to research nature. The most interesting approaches to increase motivation provided by PlantNet and Seek. Dispute negative results on Interface (for Seek, only 3,6 points) or for identification (for PlantNet, only 55 % of correct identifications), the approaches used to increase motivation are worth noting.

PlantNet approach.

One of the features worth note about on PlantNet is the social network it is based on. It consists of a feed of pictures shared by users of PlanNet. The information in the feed is devoted to classes “identified”, “unidentified”, and there is a function to display all information (by choosing “All”). The items in feed with an “identified” filter will display already identified plants by users and “unidentified” will display not-identified pictures updated by users. The most perspective is using “unidentified” feed which may be useful in a few cases:

- To solve problems with a plant which is hard to identify students have.
- To train own identification skills by providing identification of pictures of others.
- To share thoughts in the field of botanic, communicate with other researchers, and to provide social science networking.

Seek and iNaturalist complex.

The Seek-identification app provides a significantly different approach to increase students' motivation. It provides achieves for each plant students found which motivates students to get new and new researches from time to time. The effect of achievement affects the brain as exaltation and people want it again and again. This is used in games to motivate students to play again [1; 13; 44]. In the case of Seek, some factors will motivate students to research nature.

Students who use Seek can integrate it with iNaturalist application (developed by California Academy of Science and National Geographic). Which gives to students and teachers powerful systems of different instruments. The first instrument to motivate is personal journals. This feature gives to student’s possibility to provide own systematical journals. The general view of personal journal and info card on a single plant is shown in figure 11.

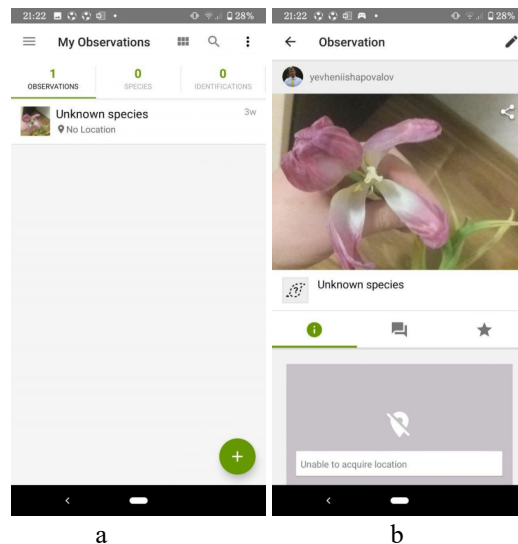


Fig. 11. The general view of a personal journal (a) and info card on a single plant (b).

The iNaturalist propose observing of plants and animals kinds student can find nearby. This feature is activated by the “Exploring All” function and choosing “My location”. Also, based on location students can use Missions which provides quests for students to do, for example, to find “Rock Pigeon”. So, students can observe nature nearby in general to study it and the program will stimulate students by completing the missions. The Exploring All and Missions functions are presented in figure 12.

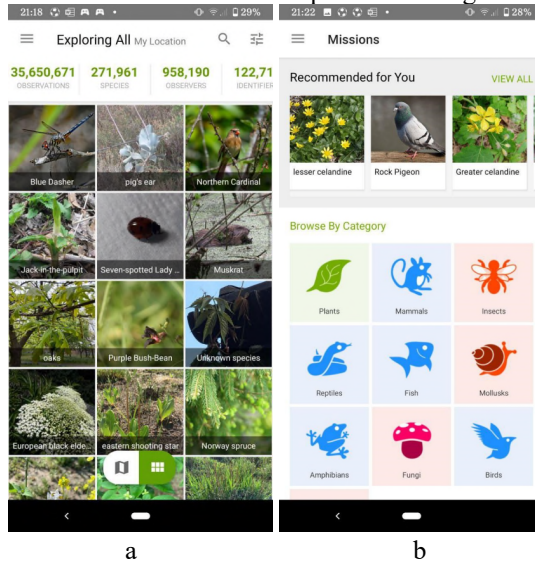


Fig. 12. The Exploring All (a) and Missions functions (b).

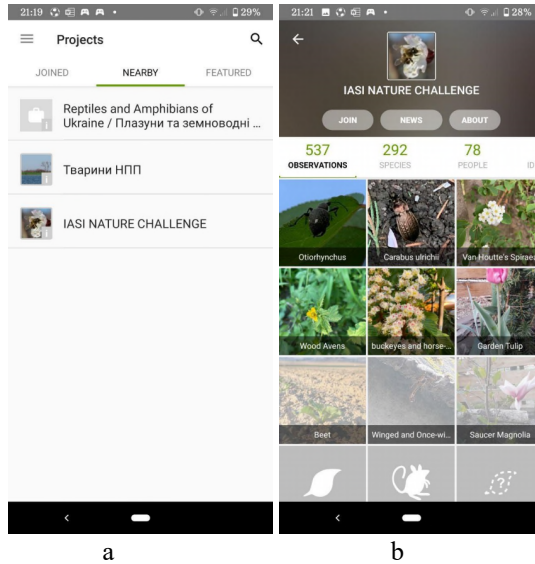


Fig. 13. The interface of the projects menu (a) and concrete project (b).

The program provides collaboration by providing projects. Users can find and chose projects they like and join be involved in them. It's worth note, that the app is very widespread and there are even projects in Ukraine. The interfaces of project selection and concrete project interface are presented in figure 13.

4 Conclusion

1. Apps related to plant identifications can be devoted to those which can analyze photos, devoted to manual identification and apps devoted to plant care monitoring.
2. It is proved that LeafSnap, Flora Incognita, PlanNet are the most usable plant identifiers apps.
3. It was shown that Flora Incognita correctly identified plant species in 71% case and PlantNet correctly does this in 55 % case which is significantly lesser than the same parameter for Google Lens (92.6 %). Google Lens was characterized by the highest mark of usability compare to PlantNet and Flora Incognita.
4. Therefore, Google Lens is the most recommended app to use during biology classes. However, for those students and teachers who do not like the Google Lens app, it is possible to use Flora Incognita.
5. PlantNet app, which is characterized by an accuracy of 55 % can't be recommended to use during biology classes at all.

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