Features of Using Mobile Applications to Identify Plants and Google Lens During the Learning Process

Zhanna I. Bilyk[1][a], Yevhenii B. Shapovalov[1][b], Viktor B. Shapovalov[1][c], Pavlo D. Antonenko[2][d], Sergey O. Zhadan[3][e], Daniil Lytovchenko[4][f] and Anna P. Megalinska[5][g]

[1]*The National Center "Junior Academy of Sciences of Ukraine", 38-44 Degtyarivska Str., Kyiv, 04119, Ukraine*

[2]*College of Education, University of Florida, PO Box 117042, Gainesville, FL 32611-7044, U.S.A.*

[3]*Individual Entrepreneur "Dyba", Kiev, 03035, Ukraine*

[4]*Taras Shevchenko National University of Kyiv, 60 Volodymyrska Str, Kyiv, 01033, Ukraine*

[5]*National Pedagogical Dragomanov University, 9 Pyrohova Str., Kyiv, 01601, Ukraine*

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Abstract: Students' motivation by providing personalized studies and using IT during classes is relevant in STEM. However, there is a lack of research devoted to justifying these approaches. The research aims to justify the choice of AR-plant recognition application, choosing to provide personalized experience during both the educational process at school and extracurricular activities. All apps have been analyzed and characterized by all interaction processes of the app with the user. In addition, the social environments of the apps and their usage during extracurricular activities are described. The didactics of the usage of AR-recognition apps in biology classes have been described. To provide usability analysis, a survey of experts on digital didactics was conducted to evaluate such criteria as installation simplicity, level of friendliness of the interface, and accuracy of picture processing. To evaluate the rationality of usage, apps were analyzed on the accuracy of plants recognition of the "Dneprovskiy district in Kyiv" list. It is proven that Google Lens is the most recommended app to use for these purposes. Considering the analysis results, Seek or Flora Incognita are both valid alternative options. However, these apps were characterized by lower accuracy. The use of mobile applications to identify plants is especially relevant for distance learning.

1 INTRODUCTION

The implementation of a mobile phone as a modern instrument into educational process has proven to achieve impressive results. Mobile phone usage during classes provides visualization of educational material, thus involving students in research and increasing their motivation for learning (Martín-Gutiérrez et al., 2015; Kinateder et al., 2014). Compared to computer approaches, mobile phone applications are characterized by the most promising advantages, including portability and the possibility to use both internal and external sensors (not commonly used). The modern educational directions include personalization and the research process, which may be achieved through the use of mobile phones (Marienko et al., 2020). However, it was proved that a general didactic approach led to a significant effect rather than using the device (mobile phone) for some separate aspects of education (Amelina et al., 2022). STEM/STEAM/STREAM technologies appear to be the most promising and relevant for the use of mobile apps.

1.1 Types of Software That Can Be Used During Education

All software that can be used during the learning process in the application of STEM can be divided into

[a] https://orcid.org/0000-0002-2092-5241
[b] https://orcid.org/0000-0003-3732-9486
[c] https://orcid.org/0000-0001-6315-649X
[d] https://orcid.org/0000-0001-8565-123X
[e] https://orcid.org/0000-0002-7493-2180
[f] https://orcid.org/0000-0002-1328-7077
[g] https://orcid.org/0000-0001-8662-8584

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desktop applications, mobile applications, and web-oriented technologies. The most perspective of information and communication technology (ITC) in education are augmented reality (Martín-Gutiérrez et al., 2015; Marienko et al., 2020; Modlo et al., 2019a; Agustina et al., 2019; Nechypurenko et al., 2019, 2023; Kramarenko et al., 2019; Oleksiuk and Oleksiuk, 2022; Rashevska et al., 2020), virtual reality (Kinateder et al., 2014; Potkonjak et al., 2016; Joiner, 2018; Lee and Wong, 2014; Sala, 2014; Hussein and Nätterdal, 2015; Zantua, 2017; Antonietti et al., 2001; Park, 2014), providing digital environments of education, including computer modelling (Sarabando et al., 2014; Sahin, 2006; Sifuna et al., 2016; Khine, 2018; Clark and Ernst, 2008), providing of ontological educational networks (Tarasenko et al., 2021; Shapovalov et al., 2021; Stryzhak et al., 2019), mobile-based education (Modlo et al., 2019b,a; Nechypurenko et al., 2023), modelling environments (Dziabenko and Budnyk, 2019; de Jong et al., 2014; de Jong, 2019; Kapici et al., 2019), providing of education visualization by including YouTube videos (Chorna et al., 2019), 3D modelling, and printing, smart physiological tools (Shapovalov et al., 2022) etc. A comparison of the most used software in the education process is presented in table 1.

Using mobile phone apps during the educational process is characterized by advantages such as multi-capabilities, interaction with students in their research, and visualization of the educational process. Mobile apps can be classified as measuring apps, analyzing apps, image recognition, and classification apps, course platforms, and VR/AR-based apps. Based on the functions of apps, they can be divided into the following categories:

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

A comparison of different mobile apps categories is shown in table 2.

Apps-identifiers are characterized by the high potential, especially in biology classes, due to their capability to provide personalized studies. Nowadays, there is an entire range of mobile applications for identifying wildlife. Such apps may help identify insects (for example, Insect identifier Photo), animals (Dog Scanner), mushrooms (Fungus) and plants (Flora Incognita, PlantSnap, Picture This). In addition, some apps (such as Seek) provide identification of a few types of nature (both plants and animals). Nonetheless, in our opinion, the most promising applications provide analysis of the static objects of nature (plants and mushrooms). It is dependent on lower requirements for image quality, meaning that one does not require a high-end expensive smartphone to use the app effectively. Therefore, Inclusion of most students in most schools is not guaranteed.

1.2 The Problem of Plants Identification

There are about 27,000 species of flora in Ukraine. Such biodiversity requires detailed description and study. Natural conditions are constantly changing, causing changes in the species composition of biocenosis. Both aspects indicate a problem with plant identification. One of the basic principles of pedagogy is the principle of a natural experiment. For a modern child, a mobile phone with Internet access is a natural environment. So, training should be carried out within the environment where a mobile phone should become a full-fledged learning tool.

Some apps can be installed on a student's mobile phone free of charge while still allowing to determine the species of plants, their morphology, the range of distribution, and more.

There are about ten applications that can be used to identify 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:

1) plant identifiers that can analyze photos (for example, Google Lens, PlanNet, Flora Incognita, PlantSnap, Picture This);
2) plant identifiers with the function of classification allow to identify plants manually. The plant's classificatory commonly contains pictures and information about plant species. However, the quality of analysis, in this case, will depend on the user's knowledge and skills, which may cause difficulties for both teachers and students. Their use in biology lessons within the STEM approach has considerable potential because it allows them to learn plant morphology. However, its efficiency depends on the user's knowledge, which may be lacking in the case of pupils (for example, Florist-X and What is a flower);
3) plants-care apps that remind to water a plant or change the soil, characterized by a lower potential

Table 1: Comparison of the most used in the education process software.

Type	Web-oriented	Mobile applications	Desktop applications
Installation	Not required	From official stores or using application file	From official stores or installation files
General requirements	Compatible Internet browser for all features support	A compatible version of Android, iOS or another mobile operating system	A compatible version of Windows / macOS /Linux or another desktop operating system
Facilities	Modelling, calculation, visualization, video presenting	Modelling, calculation, visualization, video presenting, AR, measuring with both internal and external sensors, photo analysis, AR, VR	Modelling, calculation, visualization, video presenting, using additional external sensors
Main advantages	Cross-platforming, no installation required, low device space usage	Huge possibilities, portability	Stability and variation of applications
Main disadvantages	Limited opportunities, may not start correctly depending on the platform, lack of individualization	Needs technical updates, which may be expensive (a new phone purchase may be required each two or three years)	Lack of individualization, the lesser effect of increasing motivation during STEM-education

Table 2: Comparison 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 Education
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 that analyze images and classify them	These mobile applications allow you to identify species of plants and animals using photos	Identification, Mushroom, Identify, Shazam, Dog Scanner, Identify
VR and AR-based apps	Allow virtual travel, get a spatial image of the training material.	Minecraft Earth, IKEA Place, Ideofit, Lego Hidden Side

than other application types (for example, Manager of houseplants).

Considering all advantages of plant identifiers, they were used as an object of the research. It was proven that Google Lens provides high efficiency in plant type and species identification (Bilyk et al., 2022). Furthermore, Google Lens can analyze real-life objects in AR and provide additional information using neural network algorithms. A few articles have been devoted to Google Lens that prove its relevancy and usability (du Plessis, 2015; Bilyk et al., 2020; Devi and Gaurav, 2018). However, some apps-identifiers may be more specialized and may provide better identification efficiency.

Despite the greater specialization of other applications, the research hypothesis is that Google Lens is the best plant analyzer because it may use a more extensive database, better algorithms or analysis and teaching AI using the Google crowdsource app (500 000+ installation).

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

1.3 New Features in Google Lens

Interest in learning Google Lens capabilities usage for the learning process is growing. This is due to the development of both the technology itself and the pedagogical and psychological aspects of its application. For example, Google Lens can be installed on a desktop computer via Chrome. In this version, Google

Lens allows you to not only search for similar images, but also to perform operations with text on images.

Google Lens announces the emergence of a new search algorithm Multitasking Unified Model (MUM). At the presentation, they demonstrated how it works by searching for "Socks with this pattern". As a result – a list of stores selling socks with a similar pattern was shown. There is another way to use it for other purposes, for example looking up how to fix a speed shifter on a bicycle. Simply by pointing the lens on the object and asking "How to fix it", MUM would show a video with the necessary timecode.

At a first glance, the above example with the sock pattern resembles a successful marketing move, but it also involves the moment of finding information and clarifying its proper use. For example, bicycle repair is a classic STEM project. There is a problem statement and its practical solution by way of the engineering method.

An interesting aspect of Google Lens use is facial recognition of employees working for large enterprises. The developers of Google Lens are also working hard to implement the translation feature. Photographing text in one language provides automatic translation into another. Such technology would be especially relevant for teaching deaf and dumb students.

Yue's work has shown that the use of Google Lens significantly expands the vocabulary among English for lower primary pupils (Sergeeva et al., 2021) examined the possibility of utilizing Google Lens in teaching foreign language. These studies reported that Google Lens can be applied in foreign language classes as it contributed to the optimization of the educational process by filling it with information, involving students, and successfully influencing the process of development.

Psychological and pedagogical aspects of the Google Lens application are currently being actively studied. The study results (Nguyen, 2021) showed that performance expectancy, utilitarian value, and social influence had a statistically significant and positive impact on behavioral intention, but the perceived risk had a statistically significant and negative effect on behavioral intention.

Nowadays, some aspects of Google Lens use in marketing, in learning foreign languages with students of all ages, and in biology lessons are explored. However, the effectiveness of Google Lens in recognizing living objects requires further study and comparison with other mobile applications.

2 ANALYSIS METHODS

To analyze the plant identification apps' usability, a survey of experts on digital didactics was provided. The main criteria were installation simplicity, level of friendliness of the interface, and accuracy of picture processing. Each criterion was evaluated from 0 to 5 (the higher the better). Those applications which were characterized by an average evaluation grade of more than four were used to further analyze quality of identification taking into account the condition that the application may be used by both students and teachers with a low level of ICT competence.

Analysis of quality of identification was provided by a simplified method compared to our previous research (Sala, 2014) due to the aim of this paper to obtain a general state on application plant identification accuracy. 350 images from the list of plants of the catalog "Dneprovskiy district of Kyiv" were taken to analyse the identification accuracy. The key from the "Dneprovskiy district of Kyiv" plant classification was used as a control. The vast majority of photographs of plants on this list contain distinct vegetative organs (shoots with stems, leaves, buds) and generative organs (flowers or fruits). The presence of the latter is necessary to accurately determine the species.

To analyze the data, tables with names of the plant as lines and as names of the app in columns have been created. Each successful identification was evaluated as 1 and unsuccessful as 0 (see an example in table 3).

Table 3: Example of the table of apps analyzing.

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

Finally, all obtained results, including general usability evaluation (survey) and results on identification quality, were compared with results on Google Lens to summarize information.

3 RESULTS

3.1 Analysis of the Interaction with Apps

General characteristics of the apps. The apps' databases are significantly differing. For example, the lowest number of plants in the database is in Flora Incognita (4800 species), and the highest is in PlantSnap (585,000 species).

In addition, the app's databases differ in the presence of species based on geographical locations. For example, Flora Incognita's database is very limited geographically and contains only German flora; Conversely, PlantNet's data is geographically vast and contains flora of Western Europe, USA, Canada, Central America, Caribbean islands, Amazon, French Polynesia, including, medicinal plants, invasive plants, weeds.

Login procedure and instruction. For education, the login procedure is significant because it is related to the safety of students' personal data. On the other hand, login possibility is vital to save achievements, progress, and communications which motivates the student.

Only LeafSnap does not use the additional account at all (it automatically connected to the Google account). However, almost all apps request their own account. For example, Seek requests Inaturalist account (to connect with Inaturalist social network). Apps such as FloraIncognita start with the account creation page; PictureThis starts from the page with subscription plans, which may be a disadvantage when used by students. The login process into Flora Incognita, PlantNet, PlantSnap, Seek, PictureThis, and PictureThis's is accompanied by aggressive advertising illustrated in figure 1.

The feature of detailed video instructions is available via e-mail only in the PlantSnap app (English audio and Russian subtitles available). Other apps provide instructions within themselves. PlantNet does not feature any instructions whatsoever. Instructions of PictureThis are very simple. LeafSnap's help section is not displayed with the first launch confined to a specific tab. Instructions presentation in Flora Incognita (a), PlantSnap (b), PictureThis (c) LeafSnap (d) and Seek (e, f) apps is presented in figure 2.

Data and photo input process. According to botanical science, the algorithm for determining a plant includes: establishing the life form of the plant (tree, bush, grass); studying the vegetative parts of the plant (leaves, stem). In addition, generative organs (flower or fruit) analysis is helpful to determine a specific species name. Flora incognita and LeafSnap request the addition of different parts of the given plant's pictures. The mechanism of processing can differ. For example, Flora incognita processes photos of different parts of the plant; PlantNet provides photography and then choice of the plant part (analysis of only one photo)

Geographic location is significant to identify many species. For example, Picea omorika and Picea abies are very similar species, but Picea omorika is only found in Western Siberia and Eastern Bosnia and Herzegovina. Seek, Flora Incognita, LeafSnap, PlantNet request geolocation access during the first launch. If the algorithm for determining the plant in the application includes the definition of life form, photographing the vegetative and generative organs, and the geographical location of the object, such algorithm has been evaluated as entirely correct. If the application of the plant is based on the analysis of one image in a single click, the algorithm has been evaluated as simple. The interface of different apps' photo and data input is presented in figure 3.

apps are free, but PlantSnap limits the quantity of identifications by 25 plants per day per account. The mobile application PictureThis has the biggest amount of advertising. This mobile application also allows you to identify only 5 plants per day for free. Therefore, the use of PictureThis during the learning process is quite limited. The programs can request a single photo of the plant or photos of different parts of plants (PlantNet). In addition, LeafSnap provides automatic detection of the part of the plant presented in the photo. In general, all programs allow both making a real-life photo or uploading the photo made before.

Identification results. All apps (except PlantNet and Seek) provide information on the determined plant. All data on the plant is very structured in all apps and displayed, for example, in the manner: "Genus: Fucus".

FloraIncognita, PlantNet, PlantSnap provide interaction with other sources. Both public sources such as Wikipedia and more specialized sources, such as Plants for a Future, are used for interaction. The most interactive app among them is Plant net. It provides links to Catalogue of Life, Plants for a Future, and Wikipedia Flora Incognita. When used with the Russian interface, it provides the additional link to the site https://www.plantarium.ru (figure 4). Comparison results of mobile applications that can analyze plant photos are presented in table 4.

There are some spesific functions available during identification:

- PictureThis can provide an auto diagnosis of plant's problems with pests and determination of their diseases (figure 5);

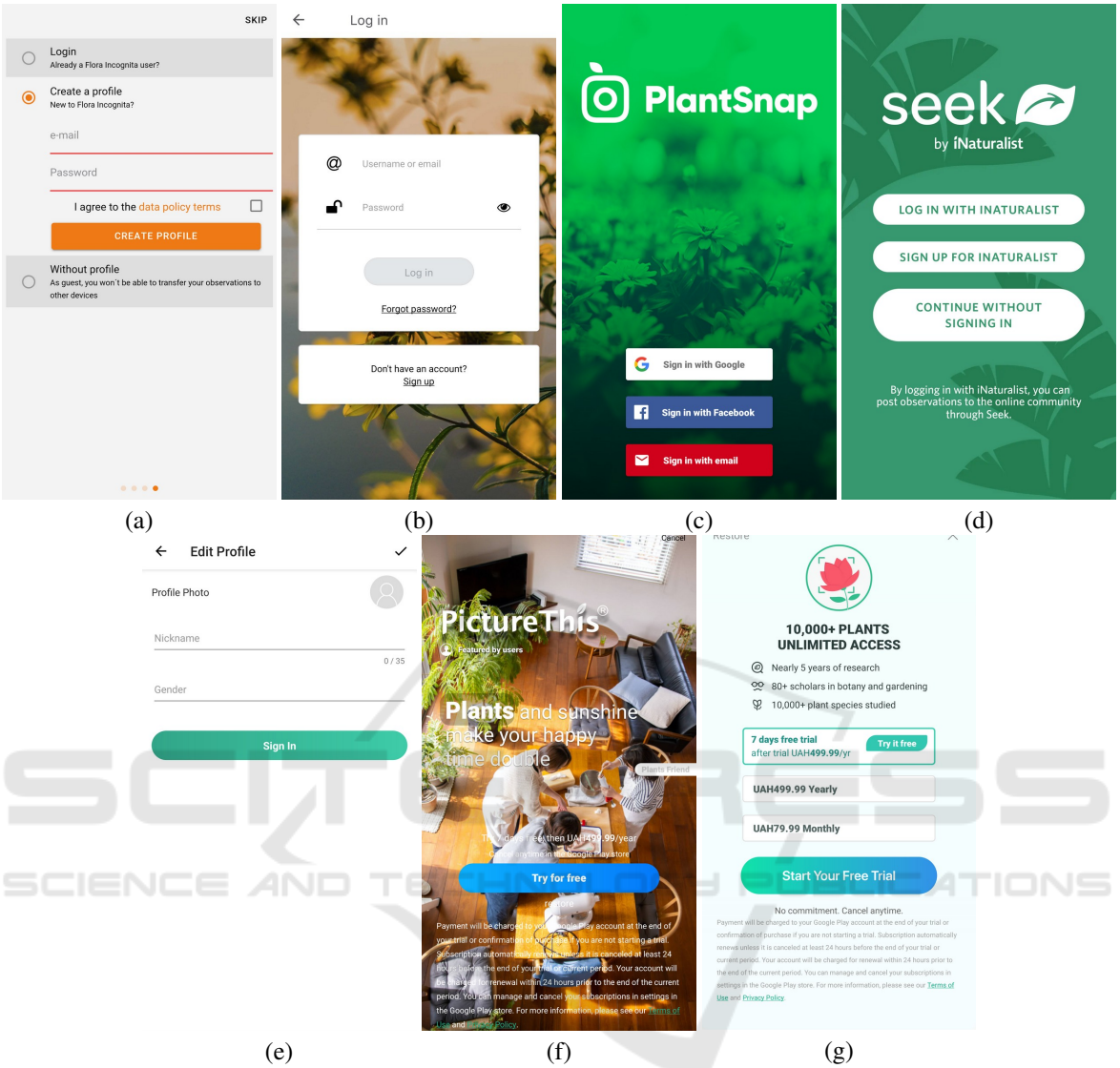


Figure 1: Login process of Flora Incognita (a), PlantNet (b), PlantSnap (c), Seek (d), Picture-This (e), and PictureThis's aggressive advertising (f, g).

- PlantSnap finds the plant on amazon and provides an infographic on solar activity, water usage and activation temperature.

3.2 Infrastructure and Social Environment

Some applications have their own approach to providing complex research of nature. Those features are useful forincreasing students' motivation to research nature. However, it is worth noting that the most developed environment is in Seek used iNaturalist application (developed by California Academy of Science and National Geographic), which delivers robust systems of different instruments to students and teachers.

Photo sharing and communications. PlantNet provides the feed of photos to identify plants shared by other users of PlanNet. The information in the feed is divided into classes "identified", "unidentified", and "All" filter (displays both identified and unidentified). The items in the feed with an "identified" filter will display already identified plants by users, and "unidentified" filter will display unidentified pictures updated by users. The most promising approach is to use an "unidentified" feed which may be helpful in a few cases:

- To help with identifying the plant
- To train own identification skills by providing

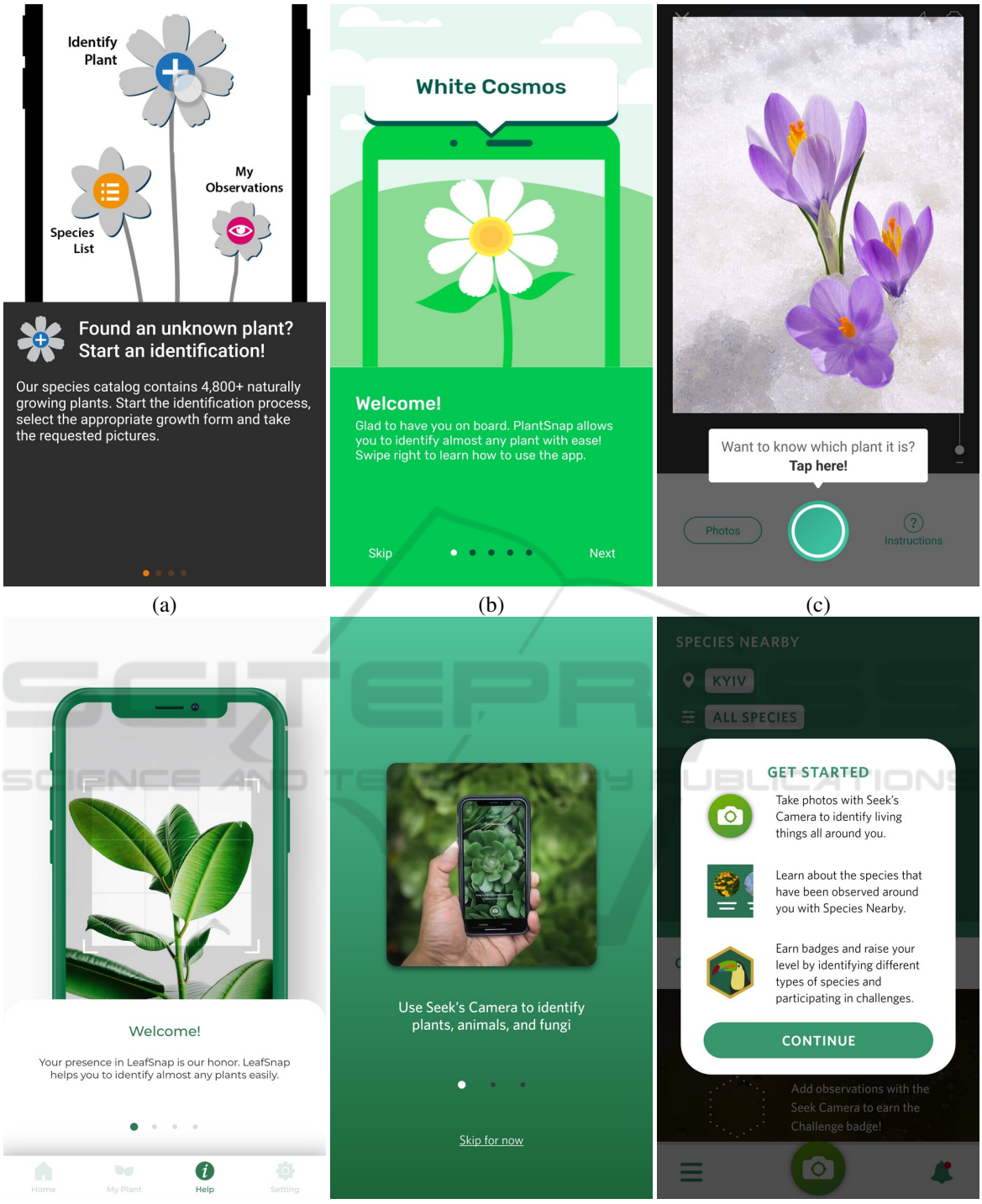
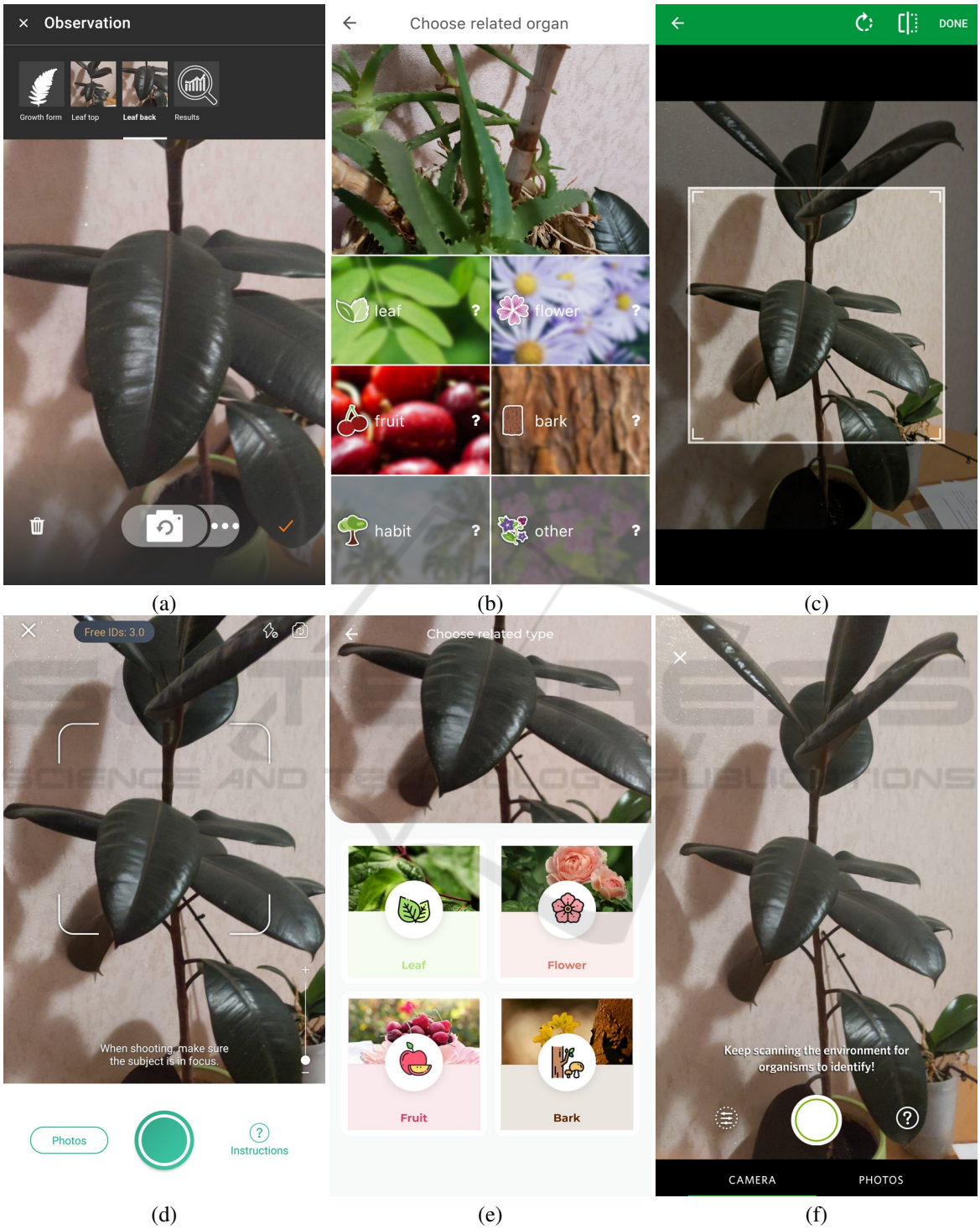


Figure 2: Instructions in Flora Incognita (a), PlantSnap (b), PictureThis (c) LeafSnap (d) and Seek (e, f) apps.

identification of pictures of others

- To share thoughts in the field of botanic, communicate with other researchers, and provide social science networking.

Personal journals. The first instrument to motivate a young researcher is providing a personal journal of observation and identification. It is a widespread feature. For example, Flora Incognita has



(a) (b) (c)

(d) (e) (f)

Figure 3: The interface of photo and data input of Flora Incognita (a), PlantNet (b) PlantSnap (c) PictureThis (d) LeafSnap Seek (e) apps.

the tab “My observations”; PictureThis has “My garden”; Leaf snap has “My plants”. However, some apps do not provide an explicitly personal journal. For example, PlantNet only saves the history of observations.

Projects and social. Seek provides collaboration

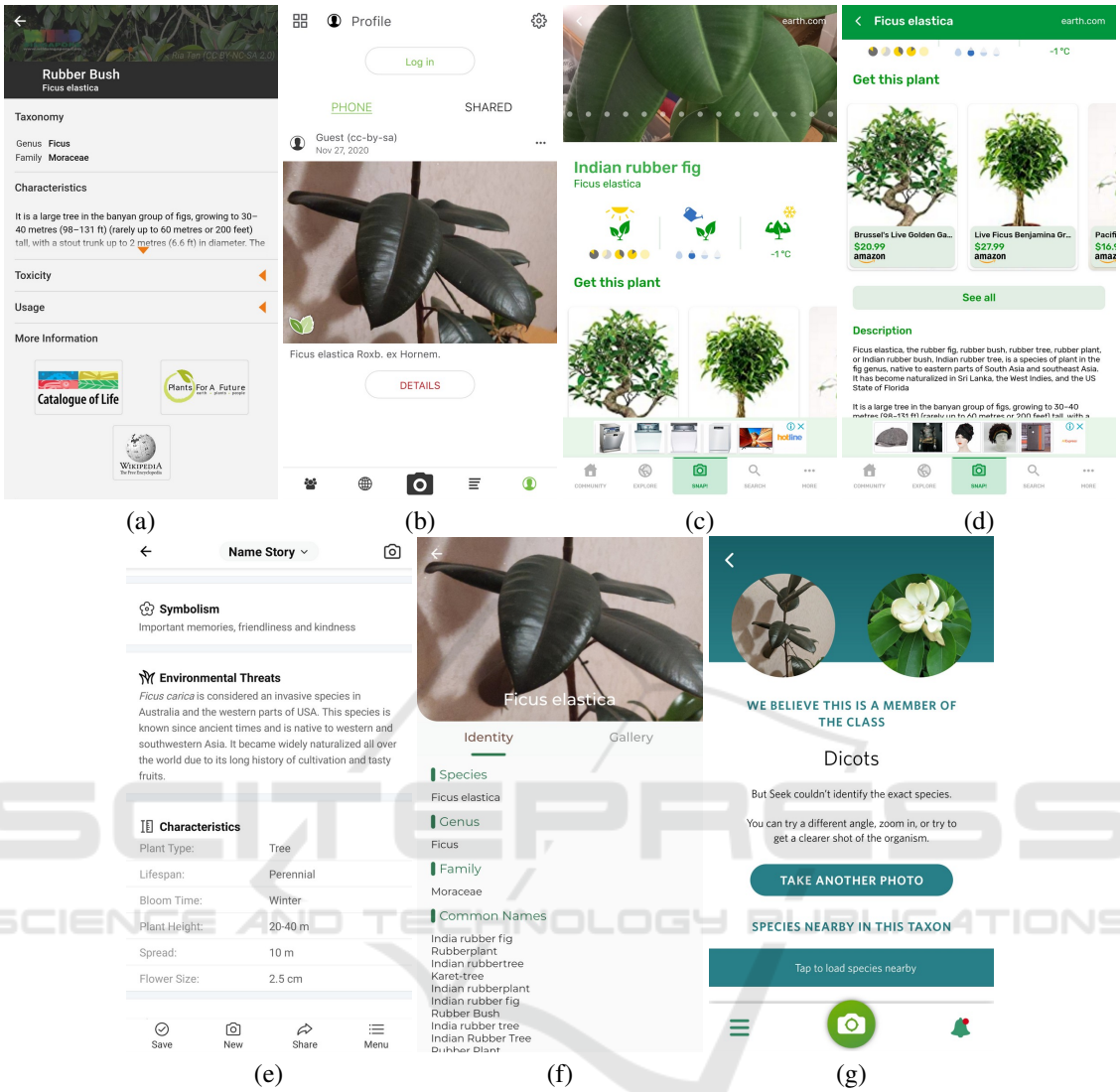


Figure 4: Data on identified plant Flora Incognita (a), PlantNet (b), PlantSnap (c, d), PictureThis (e), LeafSnap (f), and Seek (g).

through access to projects. Users can find and choose projects that they would like to join. It is worth noting that the app is ubiquitous and that there are even projects available in Ukraine. The project selection and specific project interfaces are presented in figure 6a.

Achievements. Seek-identification app provides a significantly different approach to increasing students' motivation. It provides achievements for each plant students may find, which motivates them to delve into new studies from time to time. The effect of achievement affects the brain as exaltation, and people desire it repeatedly. It is used in games to motivate students to play again and again (Abramovich et al., 2011; Hart and Albarracín, 2009; Weiner, 1985). In the case of Seek, some factors will motivate students to research nature.

The iNaturalist offers to observe plant and animal species, which a student can find nearby. This feature is activated by the "Exploring All" function and choosing "My location". Moreover, based on location, students can use Missions which gibes quests for students to do, for example, to find a "Rock Pigeon". Hence, students can observe nature nearby to study it in general terms while the program keeps encouraging students by illustrating progress through completion of various missions. The Exploring All and Missions functions are presented in figure 6b, c.

Table 4: Comparison results of mobile applications that can analyze plant photos.

Application	Number of plants in the database	Accuracy of the analyzing process	Links to other information services
Flora Incognita	4800 (only German)	The analysis algorithm is correct	Links to Catalogue of Life, Plants for a Future and Wikipedia. Flora Incognita, with a Russian interface, provides links to the Russian site
PlantNet	21920	The analysis algorithm is entirely correct	Gives only the name of the plant. Includes elements of social networks (by sharing plants student found and subscriptions). In addition, it contains links to Wikipedia.
PlantSnap	585000	The analysis algorithm is simple.	Has its own description. Searches via Amazon to give purchase options of the plant in question.
Picture This	10000	The analysis algorithm is simple.	Provides very structured information (including type, lifespan, height, flower diameter), care aspects, usage of the plant
LeafSnap	No data	The analysis algorithm is correct. Evaluation of health state (healthy and unhealthy) is included into determination process.	Contains links to Wikipedia, Pl@ntUse, Global Biodiversity Information Facility
Seek	No data	The analysis algorithm is the simplest. Achievements are given to users after some successful identifications	Has no detailed description but proposes "species nearby in this taxon"

3.3 Analysis of Application Identification Accuracy

PlantNet is the most straightforward app to install. Google Lens, LeafSnap and Flora Incognita have also simple installation procedure. Google Lens, LeafSnap, Flora Incognita, Seek have the most straightforward interface. Google Lens, PlantSnap, PictureThis, and PlantNet are characterized by the most uncomfortable identification process, which can be complicated for teachers. Results of detailed analyses on plant identification applications are presented in figure 7.

In general, Google Lens, LeafSnap, Flora Incognita, PlanNet, and Seek have proven to be the most usable after detailed research. However, the total number of points each application received is presented in figure 8.

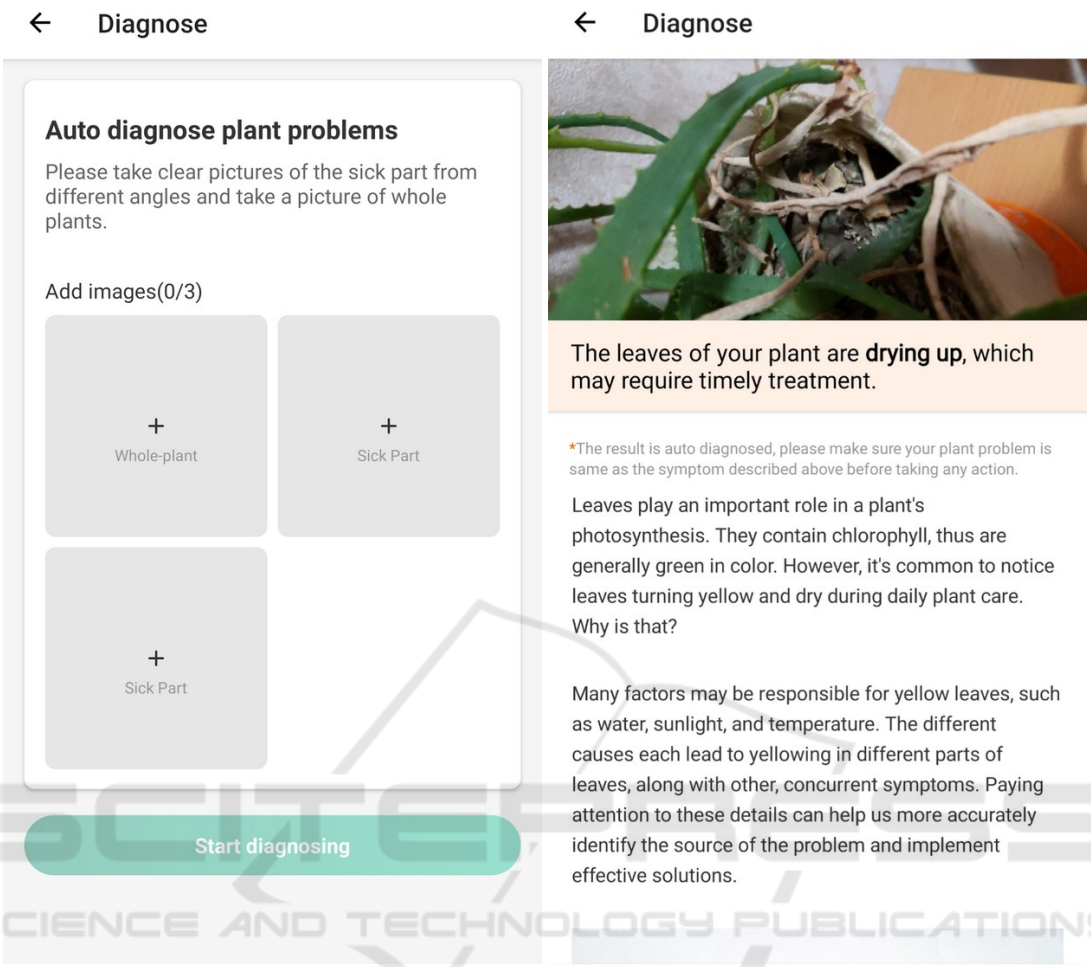
The most accurate apps are Google Lens, with 92.6% identification accuracy. Flora Incognita correctly identifies 71% of cases; PlantNet – 74%; Seek – in 76%, LeafSnap – in 76%. The PictureThis percentage of correct definitions was not determined, because this mobile application allows to identify only three plants per day for free. For a comparison of the identification plants accuracy by research applications, see figure 9.

Our previous work demonstrated that Google Lens does not differentiate native species from Ukraine. It seems that Seek, PlantNet and Google Lens mostly use data of American and European kinds of plants to train the neural network, and they have missed during identification of specific Ukrainian kinds of plants. Flora Incognita provides significantly different specific analyses; it may be due to Flora Incognita using a Russian database (similar to the Ukrainian region).

In our previous studies, it was shown that the accuracy of plant detection by the mobile application PlantNet is 55%. However, in the current test, the percentage of correct identification of plants by this mobile application has increased to 74%. This tendency indicates the ability of this neural network to learn.

The algorithm for determining plants using Seek also differs significantly. All other applications studied, except Seek, require a clear real-time photograph of the plant. Seek works with the user by interactively managing his activities in terms of image quality.

From the point of view of botanical science, the possibility to add different parts to the plants and choose the plant's type and geolocation access must



(a) (b)

Figure 5: PictureThis' app features autodiagnosis on pests and diseases function: photo input interface (a) and the result of the analysis (b).

affect the identification process accuracy. However, considering the results of the experiment, applications with a simple algorithm definition (analysis of a single image) more accurately identify plants. Therefore, it seems that internal algorithms of identification (due to higher statical characteristics of neural network) and the fullness of the database are more important than accuracy of data input or taking user geolocation into account.

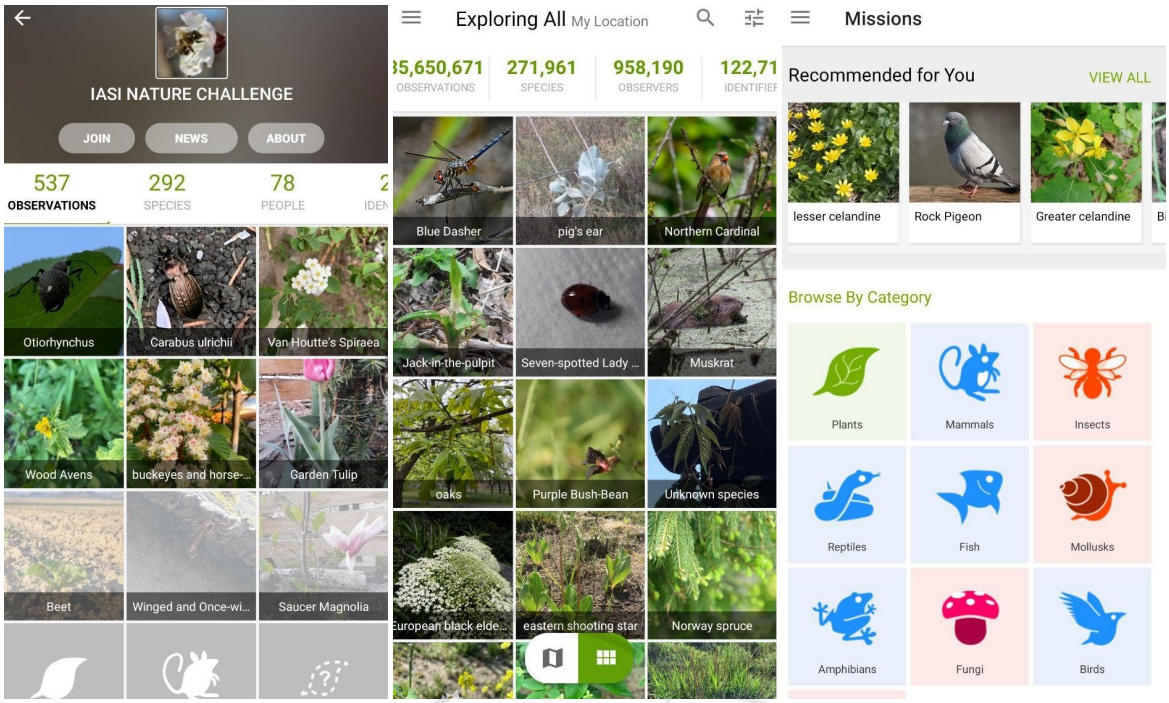
It should be noted that Seek identifies plants according to the algorithm used by professional botanists. Firstly, Seek defines the department, then the class, family, genus, and, finally, the species. Therefore, Google Lens is the most recommended app for use during classes (Bilyk et al., 2020). It is thus characterized by the highest general evaluation with 4.6 points of interface analysis, which is significantly higher than marks for other apps.

However, taking into account results of usability analysis and quality of analysis, it is possible to use Seek or Flora Incognita for students and teachers who do not like the Google Lens app for whichever reason. However, PlantNet cannot be recommended to use due to low accuracy which may result in half of incorrect analysis results.

3.4 Advantages of Using Mobile Phone Applications in the Educational Process

In our opinion, the use of mobile applications that identify plants during the education process has the following functions:

1. Function of creating a learning environment. Even in the works of Montessori (Montessori,



(a) (b) (c)

Figure 6: The Exploring All (a), Missions functions (b) and concrete project (c) functions.

1961) (a true classic of pedagogical thought), it was proven that the environment should develop the child. To a greater or lesser extent, mobile applications create such an environment. For example, Seek stimulates the child to search for new plant objects, manages the process of photographing plants, provides links to additional information about the plant, creates its own synopsis for the child, and motivates the child with "achievements".

2. Cognitive function. Only 70 hours are allotted to study all plants in Ukrainian schools. Such amount of time is insufficient for such task Mobile applications allow students to learn about the diversity of the plant world.
3. Training function. Due to the limited number of teaching hours, a teacher cannot focus enough on the development of practical skills, such as determining the life form of plants (bush, grass, tree, vine). Such skills are developed as a result of repeated training. Some applications, for instance Flora Incognita, request a definition of life form. All these functions contribute to the formation of this skill.

The use of mobile applications promotes the development of students with the following competencies:

1. *STEM competence*. When using mobile applications, students gain experience in the study of nature.
2. *Environmental competence*. Some applications, such as Seek, explain the rules of behavior in nature.
3. *ICT competence*. Mobile applications allow students to demonstrate the safe use of technology for learning.
4. *Lifelong learning competence*. The use of mobile applications teaches students to find opportunities for learning and self-development throughout life.

4 DISCUSSION

4.1 The Effect of UI/UX of the Apps on the Student's Motivation

The likelihood of students using mobile applications to identify plants depends on their interest. According to modern theories, there is individual and situational interest. Individual interest depends on the psychological characteristics of the individual. In contrast, situational interest arises in response to the peculiarities of the environment. Situational interest

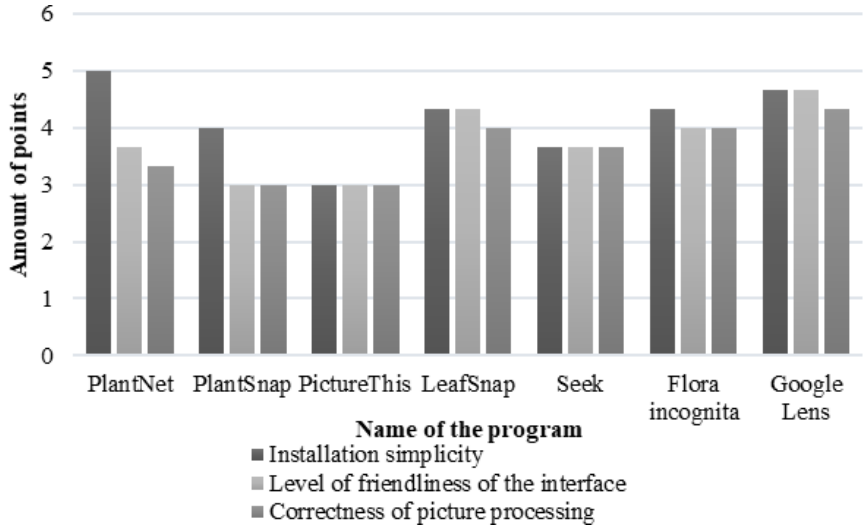


Figure 7: Results of detailed results on plants identification applications usability analysis.

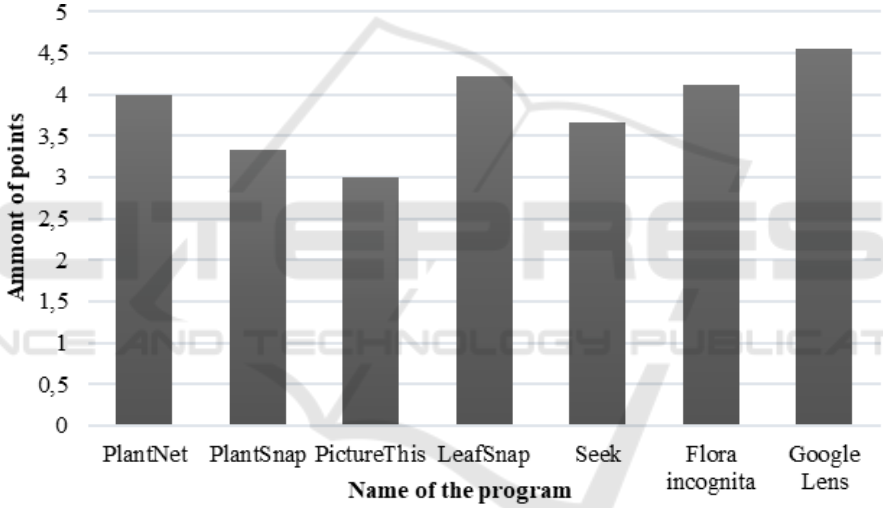


Figure 8: Integrated results on the usability of plants identification applications.

(SI) is divided into triggered situational interest and maintained situational interest (Linnenbrink-Garcia et al., 2010). Triggered-SI occurs quickly, directly, and on the "catch". Maintained-SI is a more stable form of interest in which the student begins to delve into the details. If maintained-SI deepens, this interest may become individual. According to Schiefele (Schiefele, 1991), Maintained-SI can be divided into maintained-SI, feeling component and maintained-SI, value component. These researchers believe that personality's value and sensory component support interest.

Situational interest may depend on the content of the study material. Quite a small number of students are interested in plants. However, many students may be interested in mobile applications. One way to capture users's attention is to provide mobile applications on the social network principle. PlantNet works accordingly. Users can share unique photos of plants and discuss the species. In modern pedagogics, social networks have significant didactic potential (Greenhow and Askari, 2017).

Enhancing students' motivation is an essential element, when modern informational tools usage is concerned. Motivation enhancement is significantly dependent on many factors. Situational interest plays a vital role in this context. In the case of mobile phones, students' motivation state is affected by both of them. Other factors affect motivation, such as engagement (Fredricks et al., 2004), well-being (Renshaw and Arslan, 2016; Bates and Boren, 2019; Renshaw, 2015), satisfaction (Ritzhaupt, 2019), positive

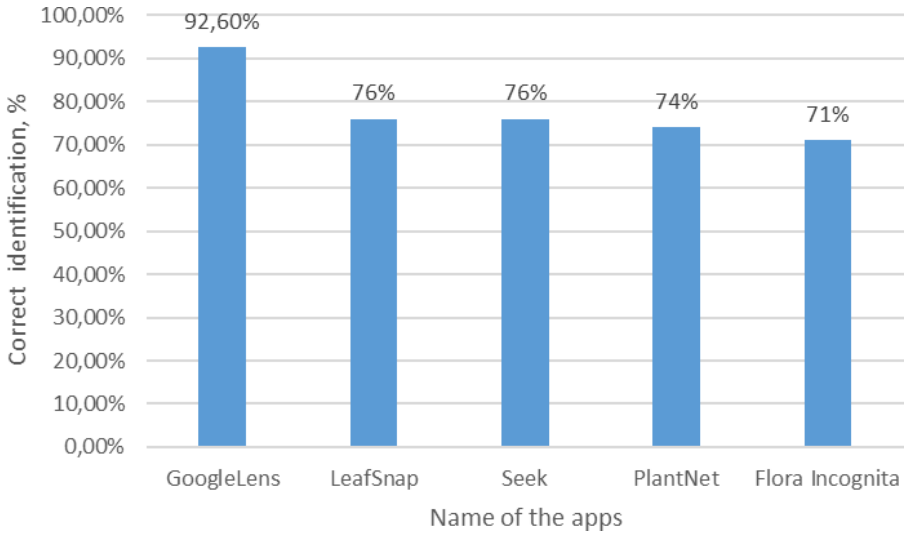


Figure 9: Comparison of the definition plants mobile apps accuracy.

and negative factors affect schedule (PANAS) (Ebesutani et al., 2012; Laurent et al., 1999). However, it seems that situational interest is caused by other factors; therefore, for analysis' sake, we will focus on situational interest. Indeed, some students will be looking for a tool that will help them satisfy their need for investigation of nature, and that causes a high level of maintained-SI when using identification mobile applications. However, triggered-SI will affect students that are not interested in nature investigation. For this purpose, the program's interface and UI/UX are very important because these are the components forming the first impression.

For example, the use of situational interest, which was triggered yet not maintained – markedly decreased from pre-test to post-test during a digital mathematics game (Rodríguez-Aflecht et al., 2018). This result may be explained by the program interface, which was neither easy to understand nor enjoyable to use. Consequently, enhancement of motivation when using such tools during biology classes becomes impossible with the interface, which contributes neither to the ease of understanding nor enjoyment of app use.

Due to the above understanding, detailed results on usability analysis (UI/UX) of plant identification applications are utterly significant (figure 7). The examples of comparison between different parts of the programs' interface are shown in figures 1-4. As shown in figure 7, the programs with the best UI/UX are Leaf Snap, Flora incognita, and Google lens.

The login process is an important part of UX, especially in the case of school usage. The experts took into account the login procedure during the evaluation of the simplicity and friendliness of the interface (figure 7). The most straightforward procedures were in Google Lens and Plant Net because it is possible to use them without additional login steps. Plant Snap and Seek also have relatively simple login procedure. Instructions are helpful, but their effect seems to have a much lesser influence on student motivation (figure 2). However, their absence may have a significant negative effect on students' motivation.

However, no programs were characterized by the absence of instructions. The simplicity and friendliness of the interface during the process of plant identification seem to deliver reverse accuracy within such a process. Even with the inaccuracy of inputting photos, some programs, such as Google Lens, nonetheless provide impressive results. Therefore, we will take into account the simplicity of such process. Google lens, PlantNet and Seek were also the easiest due to their one-click-based process. All the above steps are essential to use the factors to transfer situational triggered to maintaining interest. In most cases, obtaining additional data UX/UI will depend on maintaining situational interest. Consequently, obtaining additional data on UX/UI contribution to students' motivation will exhibit a lesser effect.

Furthermore, it is essential to consider that triggered motivation is affected not only by UI/UX, but also, by involving students in the investigation process, for instance, by providing the social network effect and communication with other young researchers – a function available in Seek.

The Seek mobile application system is interesting from the point of view of didactics. The principle of operation of this application uses gamification principles. Numerous studies have proven the high educational potential of games. In many cases, the appli-

cation of games and simulations for learning provides an opportunity for learners to apply acquired knowledge and experiment. Some things cannot be applied in real-world contexts. Games can motivate to learn, increasing the likelihood that the desired learning outcomes will be achieved. Learning is defined as the acquisition of knowledge or skills through experience or practice, and what better way to learn is there other than through a game? (Pivec and Kearney, 2007).

The student can register in Seek and get a nickname. For each plant identified, he receives an achievement and becomes a higher-level user. During computer games, the participant learns to use their knowledge in a specific situation without even realizing it. These steps allows to use knowledge, skills, and abilities automatically (Facer et al., 2001). The impact of games on motivation to learn is not unambiguous; it all depends on the game itself. Students whose situational interest trajectories were stable (either high or low) presented no changes in individual interest, yet the individual interest of students whose situational interest was triggered but not maintained markedly decreased from pre-test to post-test. Results suggest that it is vital to use game-based learning not because games are believed to be "motivating"; rather, games with proven learning outcomes should be carefully selected (Rodríguez-Aflecht et al., 2018).

When a student uses Seek for a while, he sees that first, the mobile application defines the class, then the family, then the species. This knowledge is deeply remembered.

Therefore, Seek increases the motivation to learn because, in addition to virtual awards, it offers participation in real environmental projects.

4.1.1 Alignment With Relevant K-12 STEM Education Standards in the United States and Ukraine

The main document declaring the introduction of STEM education in Ukraine is the concept of the implementation of natural and mathematical (STEM) education (Cabinet of Ministers of Ukraine, 2020). According to this document, the task of STEM in education is the formation of skills for solving complex (complex) practical problems, comprehensive development of personality by identifying its inclinations and abilities; mastering the means of cognitive and practical activities; education of a person who strives for lifelong learning, the formation of skills of practical and creative application of acquired knowledge.

In our opinion, the use of mobile applications:

1. allows to solve a practical problem (determining the type of plant, for example, if it is a parasitic plant and one needs to get rid of it);
2. comprehensive development of personality is realized through the acquisition of biological knowledge, the practice of using mobile applications, and communication with people who have similar interests;
3. the concept of lifelong learning is perfectly implemented when using mobile applications because anyone can use them at any time.

In the United States and many European countries, the ISTE 2016 standard is one of the most well-known educational standards. According to this standard, the modern student must be able to solve specific problems, making optimal use of modern technology. Such technologies include mobile applications for identifying plants which solve a specific problem. ISTE states that students use collaborative technologies to interact with others, including peers and experts, to study problematic issues from different points of view. This item is significantly supported by mobile applications for identifying plants, which are created on the principle of social networks. Using these applications, a student can discuss s photos of the most interesting plants with others. According to ISTE 2016, students jointly explore the problems at both local and global levels and use technology to develop standard ways to solve these problems. Seek promotes real projects from researching a few faunas and flora representatives to solve global problems.

5 CONCLUSION

1. Apps related to plant identification can be referred to as those which can analyze photos, devoted to manual identification, and apps devoted to plant care monitoring.
2. It has been proven that LeafSnap, Flora Incognita, PlanNet, and Seek are the most usable plant identifier apps.
3. Seek and LeafSnap correctly identified plant species in 76% of cases, PlantNet correctly did this in 74% of cases, Flora Incognita correctly identified plant species in 71% of cases, which is significantly lesser than the same parameter for Google Lens (92.6%). Google Lens was characterized by the highest usability mark compared to PlantNet, Flora Incognita, LeafSnap, and Seek.
4. Based on the above, Google Lens is the most recommended app for use during biology classes. However, it is possible to use Seek or Flora Incognita for students and teachers who do not like the Google Lens app for whichever reason.

5. The Seek mobile application can be used as a learning environment.
6. PlantNet app is characterized by an accuracy of 55% and cannot be recommended for use during biology classes.

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