Biotic invasions in Europe and the possibility of using knowledge about invasive species in education of natural sciences (geography and biology)

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Abstract: Non-native species in Central Europe, as well as in other regions in the world, are now an integral part of natural ecosystems and also human-influenced ecosystems. Teaching the issue of invasion of non-native organisms is relatively new as a subject. It is an complex process, which in the future may prove to be a problem in assessing the negative impact of invasive species on the characteristics of the geographical environment and its changes. According to the current state of the education program in Slovakia, effective since 2015, the issue of invasive species affects several thematic units of subjects such as Geography and Biology. The article provides a comprehensive overview of the issue of the education process. Nowadays, the expanding use of digital technologies in the classroom, along with personal access to the Internet, gives rise to a huge amount of new methods of accessing the new curriculum. Using mobile devices, such as tablet or smartphone, provide new and attractive ways of teaching. In this paper, the Quizlet and Socrative applications were selected as the possibility of obtaining information on invasive species.

Keywords: biotic invasions, invasive species, biotic invasions databases, education, Quizlet and Socrative applications

Introduction

Physical features such as oceans, mountains, ice sheets, and river valleys represent boundaries to the movement of individuals between populations of the same species. Over time, these separated populations diverge via drift and selection, with each population eventually forming a unique species. Climatic and geological events sometimes remove these barriers and allow individuals who represent these species to disperse through relatively long distances. During these events, long-separated species intermingle, with some eventually expanding their ranges (Lockwood et al. 2007).

Today, many organisms have virtually unlimited possibilities of transport across the planet, greatly hindering their monitoring and control. An increasing in the number of invasive species and increased speed of distribution has been observed mainly in the last three decades. This may be mainly due to extensive globalisation of trade, but also because of the phenomenon of global climate change, which can create appropriate conditions for certain species at a regional level.

At present, the unlimited mobility of people and goods in which globalization of the world economy removes the geographical barriers between species and the genetic isolation of populations and communities of co-evolving species of plants and animals. Such species may arrive in new areas through natural migration, but they are often introduced by the activities of other species. Human activities, such as those involved in global commerce and the pet trade, are considered to be the most common ways in which invasive plants, animals, microbes, and other organisms are transported to new habitats.

Biotic invasions lead to the loss of biodiversity, the homogenization of the world's flora and fauna and the reduction of biodiversity ecosystems of the planet. Invasive species are a major element of global change and contribute to biodiversity loss, ecosystem degradation, and impairment of ecosystem services worldwide.

The aim of this paper is to evaluate the possibilities for using the topic of biotic invasions in school educational programs, especially in the subjects of Biology and Geography in primary and secondary schools.

Research background

The growth of interest in biological invasions has been driven by independent growth in associated scientific disciplines according to taxonomic and habitat lines. These different kind of research share common issues, in terms of the process of invasion, and common consequences, in terms of the ecological and economic impacts of a failure to stem the tide of invaders. Blackburn et al. (2011) proposed a unified framework for biological invasions that reconciles and integrates the key features of the most commonly used invasion frameworks into a single conceptual model that can be applied to all human-mediated invasions.

Biotic invasions and invasive species of plants and animals in Europe are discussed by several authors (Beran 2008, Berezina and Ďuriš 2008, Beggel et al. 2015, Heneberg 2008, Boháč 2001, Čejka 2007, Dietrich 2001, Eliáš 2001, Fedor et al. 2014, Galko et al. 2012, Gurevitch and Padilla 2004, Chytrý et al. 2009, Jehlík et al. 1998, Kalivoda 2014, Lajtner and Crnčan 2011, Lipták 2014, Lockwood et al. 2007, Medvecká et al. 2012, Mooney and Hobbs 2000, Nentwig 2007, 2014, Pejchar and Mooney 2009, Petrusek and Petrusková 2007, Sakai et al. 2001, Soes et al. 2011, Soroka et al. 2009, Strzelec 2005, Straka and Špaček 2009, Tkadlec 2013, Tošenovský et al. 2008, Vakula et al. 2011, Vidlička 2014, Weismann and Batalik 1999, Zavaleta et al. 2001).

Nentwig (2007) tried to cover all the important aspects of biotic invasions. Nentwig (2014) focused on the 24 major European invasive species of plants and animals. In terms of the occurrence of plants listed in Europe, there are more than 5,500 non-native species of plants, of which 21 flowering plants were included among the 100 most dangerous invasive species in Europe.

Eliáš (2001) uses two approaches in the definition of invasive species. The first is a biogeographic approach, which emphasizes foreign origin. Such a view on invading organisms is very wide. From this point of view, it is considered invasive for all foreign, entrained, imported exotic species, in other words, species which live outside its natural distribution area.

However, Tkadlec (2013) believes that exotic species cannot be equated with that kind of invasive, which, unlike the exotic, must pass both phases through transport into the new territory, but also a stage of local adaptation to the new conditions associated with the further spread.

Such relatively rapid expansion of species groups is unusual enough to deserve special recognition, and palaeontologists and ecologists have given these species a whole host of names (e.g., immigrants, waifs, colonizers). This terminology can be seen in Table 1. The list was compiled according to the review of the invasion ecology literature by Lockwood et al. (2007). Other scientists may categorize the terms differently. This inconsistency creates problems for synthesis and management. The columns indicate types of species and invasion stages to which the words apply (Lockwood et al. 2007).

The most important features to support the spread of invasive species include high competitiveness (vitality, resistance to stress, long periods of flowering and fruiting, the formation of dominant vegetation in the seedling stage, rapid vegetative growth of juveniles and reproductively mature individuals), ability to survive unfavourable periods (drought, floods, distortions), ability to grow on different types of sites (other than natural habitats, wide ecological valence), good reproductive skills (vegetative reproduction by rhizomes, tubers, roots or stem parts; production of many seeds, high germination of seeds, germinating seeds does not have special demands on the environment), effective mechanisms for dissemination (long-finned seeds, seeds which float on the surface, fruits tempting animals), absence or reduced frequency of natural enemies (predators, parasites, diseases).

	Native	Non-native	Transported	Established	Spread	Impact	Invasive
Adventive	*	*		*	*		
Alien		*	*	*	*	*	*
Casual		*	*				
Colonizing		*	*	*	*		
Cryptogenic		*	*	*			
Escaped	*	*	*	*	*		
Established		*		*	*		
Exotic		*	*	*	*	*	*
Foreign		*	*	*			
Immigrant		*	*	*	*		
Imported		*	*	*	*		
Introduced	*	*	*	*	*		
Invasive	*	*	*	*	*	*	*
Naturalized		*	*	*	*		*
Non-indigenous		*	*	*	*	*	*
Noxious	*	*				*	*
Nuisance	*	*				*	*
Pest	*	*				*	*
Ruderal	*	*		*	*		*
Tramp		*	*	*	*		
Transformer		*				*	*
Transient		*	*				
Translocated	*	*	*	*			
Transplanted	*	*	*	*			
Transported	*	*	*				
Waif		*	*	*			
Weed	*	*	*	*	*	*	*

Tab. 1. Terminology commonly used for non-native species in the English language

Source: Lockwood et al. (2007)

In Europe, about 1,300 known species in the ecosystem are invasive (Nentwig 2014) and their number is continuously growing (European Union 2010).

The greatest abundance of non-native plant species in Europe is located in utilized agricultural areas, mainly in the eastern part of the United Kingdom, Northern France, Central and Eastern Europe and in the basin of the River Po in Northern Italy.

There are various theories about the issue of invasions in the regions which seek to clarify the propensity to invade the region. Probably the most famous is the biotic resistance hypothesis (Keller et al. 2011). This hypothesis points out that a region with high biodiversity and a relatively low degree of damage, particularly from human activity, seems to be more resistant to the introduction of non-native species. The reason is that ecosystems with reduced biodiversity and a relatively higher degree of the damage are likely to have more empty spaces where introduced species have a chance to settle (Elton 2000).

Although the biotic resistance hypothesis is based on logical arguments, there is very little empirical evidence to confirm it. Indeed, there is evidence (especially on larger scales) that highly diversified areas are more susceptible to the introduction of non-native species. A major problem in finding a consensus between the different theories is the difficulty in quantitatively assessing the degree of damage and the measure of the abandoned areas.

The biotic resistance hypothesis does not provide much support for the process of biotic invasions of plant species in Europe (Kuhn et al. 2003). Instead, the number of introduced species and their ability to reproduce seem to be the most important determinants of the number of introduced non-native species in any given region (Pyšek et al. 2002).

Biotic invasions mostly affected those areas in Europe which underwent marked land use/land cover transformation, such as agricultural areas, monoculture pine forests, urban areas and construction sites or landfills. On the other hand, the least amount of invasions of non-native plant species are generally in areas with natural and semi-natural ecosystems such as deciduous and mixed forests, grasslands, moor land and heath land (Chytrý et al. 2009).

Areas with a high degree of human impact tend to be invaded hardest. Damage or significant disruption of ecosystems increases the potential for invasion of non-native plants which leads to the loss of native species and increases the availability of resources for invasive species (Davis et al. 2000).

Alien species (synonyms: non-indigenous, exotic, non-native) are species, subspecies or lower taxa, which are found outside the areas of their natural dispersal potential. Their occurrence in the given region is due to intentional or unintentional introduction resulting from human activities. The EU member states have obligations and commitments under both the European and global frameworks in respect to non-indigenous species. These include prioritizing pathways for prevention, identifying the most harmful species for responses, enforcing effective early warning and rapid response mechanisms, developing indicators of trends and responses, and other management strategies (European Union 2014).

There are many databases of invasive species for the region of Europe (NOBANIS, DAISIE, ESENIAS, EASIN, ELNAIS, GISIN, IAS, REABIC etc.). The European Network on Invasive Alien Species (NOBANIS) is a gateway to information on alien and invasive species in North and Central Europe. NOBANIS covers marine, freshwater and terrestrial environments (NOBANIS 2016).

The general objectives of DAISIE (Delivering Alien Invasive Species Inventories for Europe) are to create an inventory of invasive species that threaten European terrestrial, freshwater and marine environments, project was funded by the sixth framework programme of the European Commission (DAISIE 2016).

ESENIAS (East and South European Network for Invasive Alien Species) has been initiated with the participation of all countries in the East and South Europe (ESENIAS 2017).

EASIN (European Alien Species Information Network) is an initiative of the Joint Research Centre of the European Commission. It has been established upon the recognition of the increasing serious threat posed by Alien Species in Europe (EASIN 2017).

ELNAIS (the Hellenic Network on Aquatic Invasive Species) based at the Hellenic Centre for Marine Research (HCMR). Fourteen Research Institutes/Universities and more than 77 scientists are currently carrying out research related to aquatic (marine and freshwater) alien species in Greece (ELNAIS 2017).

The Global Invasive Species Information Network (GISIN) provides a platform for sharing invasive species information at a global level, via the Internet (GISIN 2017).

Invasive Alien Species (IAS) is commonly regarded as a major threat to the biological diversity on a global scale, second only to habitat loss. In 1999, the database on species introduced into Poland was developed at the Institute of Nature Conservation, Polish Academy of Sciences in Krakow for the Ministry of the Environment. In 2003 the data were partially made available on the Internet (IAS 2017). This webpage provides up-to-date information on IAS in the Czech Republic, including current legislation, description of the most important invasive alien plants and animals as well as information on IAS prevention, elimination and eradication projects and on the most effective IAS control and regulation methods and techniques (AOPaK ČR 2017).

The Regional Euro-Asian Biological Invasions Centre (REABIC) is a largely virtual institute providing on-line information services in the area of biological invasions research and management. REABIC is serving as an independent virtual data centre for applied research and management of invasive species focusing on the Euro-Asian region and providing online services for interested stakeholders around a world (REABIC 2017).

Database of alien species in Slovakia is provided by Ministry of Environment in Slovakia (MŽP SR 5/2017). List of invasive plant species was added in 2012 (Medvecká et al. 2012) and Atlas of invasive species in Slovakia was developed in 2015 by Nevřelová and Becková (2015). The current list of invasive species of plants and animals in Slovakia is given in Annexes 2, 2a, 3, 3a in Decree 158/2014 Z. z.

Methods

The methods applied in the presented research comprised: 1. study overview of biotic invasions in the European region and their databases, 2. study overview of the possibility of using threads of invasive alien species on the basis of the educational content in the curriculum subjects Biology and Geography.

From many databases of invasive species in the European region (NOBANIS, DAISIE, ESENIAS, EASIN, ELNAIS, GISIN, IAS, REABIC etc.) authors choose two as a source of information on invasive species of plants and animals. The NOBANIS and DAISIE databases were compared as the sources of information on biotic invasions in Europe. NOBANIS is the geographical delimitation of the alien species database and DAISIE is a database of different invasive species in marine, freshwater and terrestrial environments.

Based on study overview of the educational content in the curriculum subjects Biology and Geography possible topics on invasive alien species in the educational process were designed. These topics were drafted on the basis of the content of education in subjects of Biology and Geography in Slovakia. Suitable topics were selected based on an overview of Geography and Biology textbooks (Bizubová et al. 2008, Likavský et al. 2009, Ružek and Likavský 2011, Ušáková 2010, Uhereková and Bizubová 2011, Uhereková 2014, Uhereková et al. 2016) for primary and secondary schools, which can enrich the teaching of information on invasive species. For the subject Biology suitable topics are "Life in the forest", "Life in the water", "Life on the fields and meadows" in the textbook of Biology for the 5th grade of primary school and "Living with humans and human settlements" in the textbook of Biology for the 6th grade of primary school, and also the topic "Healthy lifestyle – Basic prerequisites for health" for the 3th grade of grammar school (Uhereková 2014, Uhereková et al. 2016, Ušáková 2010). For the subject Geography suitable topics are "Natural and man-made peculiarities of Europe – Human impact on the landscape" (student's book of Geography for the 8th grade of primary school) and in the Geography textbooks for the 9th grade of primary school, also the topic "Living organisms on Earth - Human impact on the biosphere" (Geography textbooks for the first grade of grammar schools) (Bizubová et al. 2008, Likavský et al. 2009, Ružek and Likavský 2011).

The issue of biological invasions can be implemented in the educational process in different ways. For motivation and feedback in the lesson one can use mobile electronic devices such as smartphones of tablets with applications developed under the Google Android operating system. Quizlet and Socrative applications were selected as the possibility of obtaining information on invasive species. Quizlet and Socrative applications are free on the Internet (QUIZLET & SOCRATIVE 2017).

Results and discussion

NOBANIS

The European Network on Invasive Alien Species is a gateway to information on alien and invasive species in North and Central Europe. It covers marine, freshwater and terrestrial environments and provides a database on introduced species in the region, fact sheets on many of the most invasive aliens, catalogue of the regulation relevant to invasive species in participating countries, photo bank of alien species, marine key to identify invasive species in Nordic waters, catalogue of regional databases and connections to regional and global networks and projects of invasive aliens species.

The NOBANIS Network compiles existing data on alien species in a common format for all countries participating in the network.

The database of alien species includes all species that have been introduced as a result of human activities, whether intentionally or unintentionally. The core species of the NOBANIS database of alien species are organisms that are established (naturalised) in natural or semi natural ecosystems. Alien species that are only present from time to time (incidental) are included as well. Species that are constantly being introduced, but do not breed, are also included in the database.

Weed or other pests in the agricultural landscape or in forestry and animal husbandry are often alien species. The NOBANIS project covers these species as well, when the species are found in natural or semi-natural ecosystems or in native animals or plants. Introductions can also be in the form of individuals transferred from others parts of the local area.

There are several terms that have been used to name species that are transported out of their native range to become ecological or economic problems. NOBANIS uses the term "alien species", being synonymous with introduced, non-indigenous, exotic, non-native species. A species, sub-species or lower taxon (such as a variety, race, provenance or stock), introduced outside its natural past or present distribution; includes any part, gametes, seeds, eggs, or propagules of such species that might survive and subsequently reproduce (COP 6, decision VI/23).

In the NOBANIS database, the term invasive alien species (IAS) is reserved for species, which after naturalisation spread and have an effect on native fauna and/or flora; they are an alien species whose introduction and/or spread threaten biological diversity (COP 6, decision VI/23).

The database covers the territories: Austria, Belarus, Belgium, Czech Republic, Denmark, Estonia, Finland, Germany, Iceland, Ireland, Latvia, Lithuania, the Netherlands, Norway, Poland, European part of Russia, Slovakia, Sweden, and four self-governing territories: The Faroe Islands, Greenland, Svalbard and Jan Meyen, and The Åland Islands. The Faroe Islands, Svalbard and Jan Meyen, and Greenland will have separate entries, while The Åland Islands will be included in the Finnish entry.

The NOBANIS database contains 1417 invasive species (8% of the 17,696 kinds listed as alien species in the database), 1022 of potentially invasive species (6% of all detected alien species in the database), 5745 non-invasive species (32%) and 9512 unknown species (54% of all these alien species in the database) (fig. 1).



Fig. 1. The number of alien species, all NOBANIS area; Source: NOBANIS (2016)

DAISIE

The DAISIE website was developed as part of the Delivering Alien Invasive Species in Europe project funded by the sixth framework programme of the European Commission (Contract Number: SSPI-CT-2003-511202). It provides a 'one-stop-shop' for information on biological invasions in Europe, delivered via an international team of leading experts in the field of biological invasions, the latest technological developments in database design.

The general objectives of DAISIE are to create an inventory of invasive species that threaten European terrestrial, fresh-water and marine environments, to structure the inventory to provide the basis for prevention and control of biological invasions through the understanding of the environmental, social, economic and other factors involved, to assess and summarise the ecological, economic and health risks and impacts of the most widespread and/or noxious invasive species and to use distribution data and the experiences of the individual Member States as a framework for considering indicators for early warning.

DAISIE is a pivotal instrument in developing a Europe-wide strategy that encompasses both the geographical scale of the problem and unites the study of different species in marine, freshwater and terrestrial environments. With direct access to national knowledge bases throughout Europe, it is easy to obtain data on invasive or potentially invasive species and use this information in planning efforts. Data has been collated for vertebrates, invertebrates, marine and inland aquatic organisms as well as plants from up to 101 countries/regions (including islands) in the wider Europe.

In the DAISIE database, there are identified 100 of the worst invasive aliens in Europe, covering a broad spectrum of life forms and representing some of the worst species in terms of their impact on biodiversity, economy and health. DAISIE accounts for these species and provides information on their biology and ecology, habitat and distribution (including detailed maps), introduction pathways, invasion trends, impacts and management methods, including ways of prevention.

One of the great values of an inventory such as DAISIE is the ability to identify major patterns in the alien species of Europe. A series of graphical summaries of the DAISIE database are presented in Fig. 2. In DAISIE database pathways of introduction are defined as shown in Tab. 2.



Fig. 2. The number of alien species of marine, freshwater and terrestrial environments; Source: DAISIE (2016)

Unknown	Pathway not known.				
Aquaculture	Introduced in aquaculture, mariculture				
Canals	Introduced through canals				
Fisheries	Fisheries & stock movement as fish food; dispersal via fishing gear				
Vessels	Floating structures, ballast water and/or sediments in tanks, dispersal via shipping				
Leisure	Leisure activities				
Escapes	Animals, plants and their pests that escaped from captivity, laboratories, farms				
Ornamental	Live food trade, animals and plants used for ornamental purposes in parks, gardening, bonsai, etc.				
Bio-control	Introduced as biological control agent or pest of another species				
Agriculture	Introduced through agriculture				
Vessel hull fouling	Hull fouling of ships, vessels and barges				
Vessel ballast	Ballast water and/or sediments in tanks				
Forestry	Introduced for timber or re-(a)forestation on a forestry scale				
Other transport	Dispersal via transport (terrestrial)				
Other	Other. More details provided with individual records.				

Tab. 2. Pathways of introduction

Source: DAISIE (2016)

Transport pathways are defined as routes between the source of non-native species and the recipient location for these species. Ecologists who study transport pathways tend to focus on the strength of these pathways, defined as the number of species moving along them and the viability of individuals of these species once they are released (Mack 2004).

Intentional transport refers to the movement of organisms to a new area for an expressed purpose. This intentional movement of species includes a multitude of vector categories like the importation of ornamental plants, crop species, pets, bio-control, and so on (Lockwood et al. 2007).

Bio-control organisms can include insect predators, parasites, or diseases that attack the pest reducing its ability to survive or fecundity. Introductions of insect and pathogenic bio-control agents are an active scientific discipline today. In the past, however, bio-control organisms were often vertebrates (Lockwood et al. 2007). Pathways of terrestrial plants, terrestrial invertebrates and vertebrates are shown in Fig. 3, 4, and 5.



Fig. 3. The number of invasions of terrestrial plants by pathway; Source: DAISIE (2016)



Fig. 4. The number of invasions of terrestrial invertebrates by pathways; Source: DAISIE (2016)



Fig. 5. The number of invasions of terrestrial vertebrates by pathways; Source: DAISIE (2016)

The terminology of this invasion stage is still evolving; however, Lockwood et al. (2007) adopted the term usage of Mack (2004). They define a transport vector as the manner in which species are carried along a pathway, and a pathway as the route between the source region of a non-native species and its location of release. There are many potential ways to categorize transport vectors of non-native organisms: taxonomically, by transportation scheme, or by geopolitical boundaries.

Possibilities of using the topic of biotic invasions in school educational programs and subjects

According to the current state education program since 2015, the issue of invasive species affects several thematic units of subjects such as Geography and Biology. However, in practice, the issue of invasive species is reflected only in the student's book of Geography in thematic units: "Human impact on the landscape" in the student's book of Geography for the 8th

grade of primary schools (Ružek et al. 2011), and "Human impact on the biosphere" in the textbook of Geography for the first grade of grammar schools (Bizubová et al. 2008). The issue is also mentioned in the characterization of Australian flora and fauna in the student's book of Geography for the sixth grade of primary schools (Likavský et al. 2009). In the first two cases, there is a brief introduction of invasive organisms as a social problem on a global scale with the best-known and most common representatives of invasive organisms in Slovakia and in Europe.

The content of the current state education program for Geography, as a spatial science should contain the issue of invasive alien species in an appropriate form. The content of education should be focused on the spatial distribution of invasive alien species in Europe and their impact on specific countries and the methods of their control.

Distribution of invasive species in Europe and their impact has been in the thematic topics "Natural and man-made peculiarities of Europe – Human impact on the landscape" (student's book of Geography for the 8th grade of primary schools) and in Geography textbooks for the 9th grade of primary schools.

Enhanced knowledge of invasive species in Europe, as well as new knowledge including the origin and manner of introduction of invasive species in Europe is justified in the thematic topic "Living organisms on Earth – Human impact on the biosphere" (Geography textbooks for first grade grammar schools).

A suitable place for the inclusion of invasive alien species topics is in the curriculum of the subject Biology in primary and secondary schools. The spiral arrangement of the contents of Biology in primary schools gives an assumption for the gradual increase knowledge about current environmental problems of invasive alien species spreading, particularly in relation to human health (e.g., allergy), but also in relation to biodiversity of ecosystems and economical damages. Thematic topics such as "Life in the forest", "Life in the water and on the shore" and "Life on the fields and meadows" in the textbook of Biology for the 5th grade of primary schools, as well as a whole "Living with humans and human settlements" in the textbook of Biology for the 6th grade of primary schools, are suitable for inclusion of these issues. This would be a mentioning of the most dangerous invasive species and their impact on ecosystems, respectively on human health.

In the curricula of secondary and grammar schools, the content of living organisms on the Earth is partitioned into aquatic and terrestrial environment. In the topic "Life in the water", there is space for mentioning non-original invasive species of watercourses (e.g., *Elodea canadensis, Ondatra zibethicus, Myocastor coypus*). Disrupting aquatic ecosystems rival suitable conditions for life and suppress populations of native species. Also worth mentioning, that non-native invasive species along river banks (e.g., *Impatiens glandulifera, Fallopia japonica*) with a strong root system supports shoreline erosion due to the ejection of the original vegetation. In the topic "Living with humans" in the textbook of Biology for the 1st year of grammar schools, the space for the mentioned issues, especially in the topic "Plants and fungi in the service of man" where there is imported ornamental foliage, parks and gardens, it might be appropriate to mention those that have become invasive and pose a significant threat to biodiversity of ecosystems (e.g., *Robinia pseudoaccacia, Solidago giganthea*). Selected invasive species included in the teaching of subjects Biology and Geography are defined in tab. 3.

Non-native invasive species in relation to human health undoubtedly have a place in the topic "Healthy lifestyle – Basic prerequisites for health" (the 4th year of grammar schools), where the quality of the environment is mentioned as an important prerequisite for human health. It is in this topic in which the effects of invasive alien species are explained to the greatest extent. This is the extrusion of native species, creation monocultures changing the overall appearance and functioning of ecosystems, excessive production of pollen and toxic substances contained in the bodies of plants causing health problems or occupation of sites that prevent people access to recreational zones.

Subject	School Year	Thematic curriculum	Invasive plant species	Invasive animal species	
Biology	5 th grade of primary school	Life in the forest,	Elodea canadensis, Fallopia	Hyphantria cunea, Ips	
		Life in the water, and on the	japonica, Fallopia sachalinensis,	duplicatus, Arion Iusitanicus,	
		shore,	Heracleum mantegazianum,	Oxyura jamaicensis, Sciurus	
		Life on the fields and	Impatiens glandulifera, Solidago	carolinensis, Ondatra	
		meadows	canadensis	zibethicus, Myocastor coypus	
	6 th grade of primary school	Living with humans and human settlements	Fallopia sachalinensis, Solidago	Arion lusitanicus Frankliniella	
			gigantea, Iva xanthifolia,	occidentalis Harmonia	
			Helianthus tubesosus, Ambrosia	axvridis. Trachemys scripta	
			artemissifolia		
	7 th grade of	Man and his body (health	Ambrosia artemissifolia,	Vespa velutina nigrithorax,	
	primary school	and health risks)	Heracleum mantegazianum	Ondatra zibethicus	
	8 th grade of primary school	Environment of organisms and humans	Robinia pseudoaccacia,	Orconectes limosus, Arion	
			Ailanthus altissima, Fallopia	lusitanicus, Harmonia axyridis,	
			japonica, Ambrosia artemissifolia	Trachemys scripta	
	9 th grade of primary school		Ailanthus altissima,	Ips duplicatus, Harmonia	
		Ecological conditions	Heracleum mantegazianum,	axyridis, Trachemys scripta,	
			Robinia pseudoaccacia	Oxyura jamaicensis	
	1 st year gram- mar school	Living with humans	Fallopia japonica, Robinia	Arion lusitanicus,	
			pseudoaccacia, Solidago	Harmonia axyridis,	
			pseudoaccacia, Solidago giganthea	Trachemys scripta	
	6th grade of		Robinia pseudoaccacia Fallopia japonica, Robinia pseudoaccacia, Solidago giganthea Phytophthora cinnamomi	Apis cerana, Solenopsis	
Geography	primary school	Australian flora and fauna		invicta,Bufo marinus, Vulpes	
	F		F H H H H H H H H H H	vulpes, Oryctolagus cuniculus	
	8 th grade of primary school 1 st year gram- mar school	Europe's problems - issues related to the spread of invasive organisms	Fallopia japonica, Robinia	Harmonia axyridis,	
			pseudoaccacia, Ambrosia	Vespa velutina nigrithorax	
			artemissifolia, Heracleum	varroa destructor,	
			mantegazianum	Tracnemys scripta	
		Human impact on the	Fallopia japonica, Robinia	Harmonia axyridis,	
		Biosphere	pseudoaccacia, Solidago	Lepunotarsa decemineata,	
			gigantnea	Arion Iusitanicus	

Tab. 3. Inclusion of invasive species in the teaching of Biology and Geography subjects at primary and secondary schools

In textbooks of vocational secondary schools, such as trade academies, it would be appropriate to offer practical classes on the issues related to the economy, where non-native invasive plants cause significant economic losses. The conditions of such a loss include minimum spatial requirements where they are able to germinate and grow in the cracks of sidewalks and buildings in settlements, thereby distorting these areas, and thus requiring further maintenance. They also grow on the banks of rivers, lakes, near beaches and on the edges of forests which make it more difficult to access sites serving for recreation, reduces attractiveness and use of areas for tourism.

The issue of biological invasions can be implemented in the educational process in different ways. We consider field excursions the most appropriate form of teaching the topic in the field (outdoor) as they allow to observe and to monitor the occurrence of invasive species in the field. The most important problem we consider is that many teachers do not have enough information about the issue of species invasions. At present, there is no comprehensive didactic material that would contain the relevant information on biological invasions and lead to the possibility of their performance in an attractive way in the learning process. Individually, promotional material issued by the State Environmental Protection of Slovakia is available, but is intended rather for the public (Cvachová et al. 2002, Cvachová et al. 2005, Cvachová et al. 2007, Cvachová and Gojdičová 2004, 2007, Cvachová et al. 2008). We also consider the use of invasive plants and animals atlases (Ružek and Noga 2015, Nevřelová and Becková 2015) which are often freely available online. Also these atlases include suitable ideas for work with students in dealing with the issue of biological invasions.

The theme and its treatment in the form of discovery and localization of invasive species in the selected region are suitable for use in project learning.

QUIZLET AND SOCRATIVE APPLICATIONS

Nowadays, the expanding use of digital technologies in the classroom, along with personal access to the Internet, gives rise to a huge amount of new methods of accessing the new curriculum. Assuming that it discloses the issue of the spread of invasive alien plant and animal species in Europe, there are many different teaching methods that can be used.

New and expanding ways of teaching may be working with tablets or smartphones. The possibilities for their use are different. It is possible to have the electronic form of the Atlas of invasive plant taxa in Central Europe saved in the tablet and to use it directly in the field. In the case of using a smartphone to access the Internet, students can obtain information from the online atlas as well as supplement the available websites. Students are allowed to use information from the atlas for monitoring outbreaks of invasive species. Tablets also enable them through other applications to obtain information on their position on the principle of GPS, thus becoming a pioneering work for student and researcher. Tablet usage is justified in project teaching, for example invasive species photography, filming space in which invasive species occur and so on. For motivation, as well as for finding feedback, tablet apps available in the Google Android operating system can also be used. In this work, we present only two of them which are likely to attract students and through which they are able to obtain information on invasive plants.

Where possible, learning with digital technologies, such as interactive whiteboards or tablets and the appropriate use of a variety of applications, are helpful in mediating the curriculum, consolidating acquired knowledge and student evaluation. One such application is Quizlet. This application is accessible on the internet and can be downloaded on Google Android operating systems. It's an application which connects concepts and definitions and creates associations, aids bonding and repeats information acquired in the learning process. The concepts can be supported for thematic photography and used to practice three activities. The first is a form of flashcards, where on one side is written the term, and its definition on the other side. This old, proven method shall be repeated in digital form in a new dimension. The second is called Learn form, which consists of writing responses (concept) to questions (definition). Another form is the test form, where applications based on established concepts and definitions automatically compile test questions (short answers, more options and True/False). The last is a form of pairs (scatter or match), which show the various terms and definitions and should be acknowledged in a row of related terms and definitions, and then disappear. The activity is supported by a timer which counts the time in which the student completes the activity, it promotes the competitiveness of students, their interest in verifying their knowledge, strengthening curriculum and subsequent evaluation of individual activities (fig. 7). Applications can be created according to the teacher's own requirements and expectations (use Slovak nomenclature, or use pictures, photographs of given species).

The Socrative application supports the creation of tests and the testing of students in a classroom or anywhere with Internet access. Socrative operates in two forms, namely teacher and student. The application Socrative Teacher has the possibility to create tests consisting of these questions types: more options, True/False and short answers. Furthermore, there is the ability to edit tests and start testing of students. The advantages are the use of the test in the classroom through interactive tablet, immediate evaluation and comparison of results and give feedback to students. The application Socrative Students is able to log into a specific test created by teachers on the basis of a code which has each test. Before starting the test, it is possible to adjust the options which consist of the names of students, and will reveal or hide during testing whether the questions and answers will be in the order they were created, or the system will randomly scatter and offer immediate feedback on the student answers for each question.



Fig. 6. The interface of the Quizlet application. Pairs form allows combining the related terms. The timer records the time it takes to solve the tasks. Source: Noga (2017)

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Conclusions

Current legislation and European policies already provide part of the solution to the problem of invasive species. However, there is no uniform system for monitoring and controlling of invasive species and their effects on European biodiversity. The project DAISIE (Delivering Alien Invasive Species Inventories for Europe), supported under the Sixth EU Framework Programme for Research in Europe has identified 10,822 non-native species, of which 10-15% is projected to have a negative impact on the economy or the environment. Isolated islands with high biodiversity, including most European overseas territories are particularly vulnerable to invasion, which can also have a disproportionate impact on local livelihoods, culture and economic opportunities.

Teaching the issue of invasive species is important for the society as the effect of such species in our environment has consequences which are already noticeable and tangible. Therefore, it is practical to know about their basic cognitive respects, life cycle and impact on the environment and society. It is necessary to know how to handle them properly in order to prevent greater damage, and that the general public has sufficient information on how to prevent their spread. These are the reasons why it would be appropriate that the topic of invasive species should be inserted into the educational process. Multi-disciplinary approach in investigating the invasion of species, such as in ecology, biology, geography or economy increases the dynamics of the teaching process. Learning with digital technologies, such as interactive whiteboards or tablets and the appropriate use of a variety of applications is helpful in mediating the curriculum, consolidating the acquired knowledge and student evaluation. The Quizlet and Socrative applications allow using the issue of invasive species in the learning process.

There is a lot of available resources referring to the biological invasions in general and also specifically aimed at non-native invasive plant species. Similarly, the amount of research results on modern didactics and alternative forms and methods of education is huge, as is the amount of audio-visual resources on the Internet. Presented results of the research were partly verified at several primary schools in the Bratislava region. Noga (2017) published a part of the results noting that the implementation of non-traditional methods in teaching brings many benefits to the teacher and the pupils. The results of the research and its verification can also be used in the creation of new textbooks for primary and secondary schools.

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