TEALEAF

(Erasmus + Project 2014-FR01-KA201-008559)

Academic book

Edited by

Dušan Krnel

University *of Ljubljana*
Faculty of Education

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PREFACE

This book is one of the output-results of a collaborative research effort between researchers from the various partner institutions involved in the project. The aim of the project was to improve both learning and teaching related to biodiversity using serious games in classrooms (so-called apps) and to highlight the need to think critically about the pedagogical facets and potential of apps. One specific aspect of the project was the inclusion of a number of science teachers and students in the process. These two groups served as a source of data that was collected over the course of various activities. An analysis of this iterative process is published as a body of research papers herein.

We hope this book represents a useful new approach to using apps in teaching and learning about biodiversity and in the teaching of science in general.

We thank the groups of teachers from the five participating countries who agreed to take part in this collaboration. Thanks to colleagues who joined the research part of the project; and finally, we thank our colleagues from Laval for their highly supportive and democratic leadership of the project.

Dušan Krnel

1 PARTICIPATING INSTITUTIONS

Direction Diocésaine de l'Enseignement Catholique (DDEC) de la Mayenne

The Direction Diocésaine de l'Enseignement Catholique (DDEC) de la Mayenne represents a large network of private schools that is part of the French public school system of education (under contract with the Ministry of education). It is situated in the west of France in LAVAL.

1500 teachers and 22780 pupils distributed in 134 schools:

- 11000 pupils in 101 pre-primary and primary schools
- 6760 students in 14 secondary schools (colleges)
- 5020 students in 11 high schools which offer courses in the fields of general education, technological and vocational education.

4 strategic aims:

- Promote an educational climate dedicated to the person.
- Innovation to enable children and young people to progress.
- Introduce and support changes.
- Propose roads of Christian faith.

Direction of Catholic Education in Mayenne has got several missions:

- To identify schools network's needs of in fields of organization, recruitment, education, ICT, pastoral, pedagogy, management and to propose appropriate answers.
- To organize the recruitment of both head teachers and teachers and their replacement in case of absence.
- To make the link with the territorial representatives of the government within the framework of the contract with the educational public ministry (inspectors, regional education authorities, regional council, mayors association, etc.).
- To participate in initial teachers training in partnership with UCO (Université Catholique de l'Ouest).
- To propose in-service training for teachers, head teachers and non teaching staff in connection with training institutes.
- To provide teaching teams with e.g. organizing research-action workshops, seminars, etc.
- To watch the development and evolution of schools network in dialogue with ministry of education.
- To take care of the maintenance and development of schools buildings.
- To provide schools with digital working environments.
- To provide schools with suitable conditions for students with specific needs.

Staff involved in the project: Marie-Aline Vivier-Laroche, Marie-Line Guesdon, Mickael Gac, Christine Mortoire

University of Almeria

The University of Almería (UAL) (http://www.ual.es) is a non-profit organization which was created by the Andalusian Parliament in 1993. That was the beginning of a crucial period for the construction of the University and the planning of the future development. Today it is one of the youngest and most dynamic universities of Spain with about 14,000 students (and almost 600 doctorate students), more than 800 lecturers, organized in 13 departments and in more than 100 research groups, and more than 500 administrative staff. The UAL participates in various mobility programmes such as: ERASMUS, ISEP, Pima, Anuies… and it has more than 650 students from all over the world.

The main purpose of the University of Almeria is to adapt its services to the new demands of the society in order to reach the quality and efficiency objectives in teaching, research and management. Nowadays the University of Almería offers the students the possibility of studying 34 degrees courses, 30 doctoral programmes, 57 official masters' programmes and 15 non-official masters' programmes. It also proud of its modern facilities among which we can find its lecture theatres buildings, an auditorium, an indoor sport centre with a swimming pool and outdoors sport tracks and tennis courts. Apart from the degree courses, the student can avail of a broad range of courses designed by the University, such as specialist courses, expert courses, master's programmes, etc., and a large offer of cultural and sport activities, which intend to satisfy the academic and extra academic demands, coming not only from the university community but from the society in general. There are more than 20 summer courses every year, which are followed by more than 1,300 students. The University of Almería has a solid commitment with research and investigation, featuring in the third position in the Andalusia scientific production ranking, with 300 research contracts signed with companies, 70 patents registered and 700 published works.

Staff involved in the project: Rubén Martinez, José Luis Ruiz Real

Dublin City University

Dublin City University (http://www.dcu.ie), or Ollscoil Chathair Bhaile Átha Cliath in Irish, was founded in 1981 and comprises over 17,000 students including over 2700 postgraduate students, of whom over 700 are research students. The University is consistently ranked among the top young universities globally, appearing in the QS Top 50 under 50, and Times Higher (THE) Top 100 under 50. DCU incorporated St. Patrick's College of Education, The Church of Ireland College of Education, Mater Dei Institute of Religious Studies and Education, and All Hallows College in 2016, all founded in the 19th century as training colleges.

Dublin City University:

- Promotes world class excellence in research and innovation in its core areas.
- Focuses on research and innovation which can make a difference to problems that matter to industry and society.
- Provides a business-friendly environment to multiply the effects of its activities in research and innovation.

DCU's strategic plan "Transforming Lives and Societies". DCU's mission is to transform lives and societies through education, research and innovation. DCU's Core Principles capture the distinctive essence of DCU: Transformation, Enterprise, Translation and Engagement. This is accomplished by discovering, analyzing, expanding, and disseminating knowledge, by developing creative and critical thinking and by fostering skills and learning.

Dublin City University aims to transform lives and societies through education, research and innovation. In order to achieve this, DCU has arranged much of its research activities to address major areas of societal and economic needs – health, information technology, sustainability and resilience. To ensure that DCU research increases its real-world impact, we are focusing on priority areas where DCU has recognized strengths and where society is facing significant challenges. These areas form four research and enterprise hubs:

- health technologies, and the healthy and aging society,
- information technology and the digital society,
- sustainable economies and societies,
- democratic and secure societies,

The resources and expertise in the hubs will be reinforced by additional expertise in three cross-cutting platforms that provide support in key areas of science and technology, business processes and social sciences. In each hub, researchers from across our five faculties (DCU Institute of Education, Engineering and Computing, Humanities and Social Sciences, Science and Health, and the DCU Business School) can work together to tackle problems in new ways and deliver innovations of benefit to society. The researchers will be supported by integrated administrative, communications and business development teams to make the most of resources and to engage effectively with external enterprises. Each hub and platform will be guided by an academic director who will build on existing strengths and develop new activities for future growth.

A Science and Technology Enhancement Platform (STEP) will link key areas of science and technology and allow us to make best use of our existing resources. It will enable DCU to develop infrastructure that will be critically important for future research in core science and engineering disciplines and in addressing several key societal challenges.

The Societal Impact Platform will help to incorporate societal perspectives into our research and to increase public engagement. Dublin City University encourages researchers to consider six key aspects to enable a better alignment of their research with the values, needs and expectations of modern societies. These include: engagement, gender equality, science education, open access, ethics, and governance.

Staff involved in the project: Thomas McCloughlin, Sandra Austin, Penny Humby

University of Ljubljana

The University of Ljubljana implements and promotes basic, applied and developmental research and is pursuing excellence and the highest quality as well as the highest ethical criteria in all scientific fields and art. In these areas of national identity the University of Ljubljana specifically develops and promotes Slovenian scientific and professional terminology. Based on its own, Slovenian, and foreign research, the University of Ljubljana (UL) educates critical thinking top scientists, artists and professionals qualified for leading sustainable development, taking into account the tradition of the European Enlightenment and Humanism and with regard to human rights. Special attention is dedicated to developing talents.

The UL encourages interdisciplinary and multidisciplinary study, exchanges results of achievements in science and art with other universities and scientific research institutions, thus contributing to the Slovenian and world knowledge treasury as well contributing to the transfer of these achievements among the students and other users.

The UL cooperates with organizations from economy and service in public and private sector, with state organizations, local communities, and civil society. With this cooperation accelerates the use of own research and educational achievements and contributes to the social development. With active responses to events in the environment represents the critical conscience of the society.

The Faculty of Education of the University of Ljubljana educates and trains teachers and other professional workers in the field of education. We train all kinds of professionals, from preschool and primary teachers to teachers who are specialists in teaching two subjects or subject areas in primary school, as well as in certain secondary schools. The advantage that graduates from the Faculty of Education have lies precisely in having been trained for at least two subject areas, which increases their employment opportunities as well as responding to the needs of school practice.

In addition, to the traditional teachers' programmes, the Faculty of Education of the University of Ljubljana is the only institution in Slovenia that trains specialists for inclusive education and the education of children and young people with special needs. It does this through the study programmes of social pedagogy and special and rehabilitation pedagogy, covering the entire spectrum of special needs: from behavioural and social difficulties to all kinds of impairments (vision, hearing, speech, movement) and learning difficulties.

Fifty years of evolution of Faculty of Education could be divided into three parts: (1) period of Higher Education School (1947-1964), (2) period of Education Academy (1964 - 1987), and (3) period of University study programmes (since 1987).

The faculty executes seven first cycle study programmes (BA/BSc) and twelve second cycle study programmes (MA/MSc). In the 2009/10 academic year, we commenced the execution of a new doctoral study programme entitled Teacher Education and Educational Sciences, which is divided into the two scientific areas of the programme title: Teacher Education and Educational Sciences.

The Faculty of Education regularly organises supplementary professional education, as well as pedagogical andragogical (adult) education. Particularly in recent years, scientific-research and artistic work have been strengthened at the Faculty of Education, although many teachers have also worked in these areas previously. A range of teachers have successfully established themselves at symposia and conferences in Slovenia and abroad, as well as been included in international research projects in which they collaborate with similar universities/faculties in Slovenia and abroad. The primary research undertaken at the Faculty of Education of the University of Ljubljana is from the areas of educational sciences, natural sciences, social sciences and the humanities.

At the Faculty of Education we are aware of the importance of the pedagogical profession and endeavour to ensure the quality of our educational work in all of its facets. Our strategy is to become a leading university in teacher education that provides the highest quality research and teaching, and engages locally and internationally on the issues and debates of the current issues in today's education contexts. Driven by research in various educational disciplines, and stimulating learning, the internationally oriented university informs and changes their practice and thinking constantly.

Staff involved in the project: Irena Nančovska Šerbec, Gregor Torkar, Dušan Krnel

University of West Bohemia

The University of West Bohemia in Pilsen (UWB) is the only public institution of higher education based in the Pilsen Region. Currently, the University has nine faculties consisting of 57 departments and 2 institutes of higher education. 13 118 students studying at the University can choose from a wide of range of undergraduate, postgraduate and doctoral study programs, the choice of form of study, i.e. a full-time, part-time or combined form, being a matter of course.

The educational activities at the University of West Bohemia in Pilsen include life-long learning programs for the general public in the form of lectures, courses and comprehensive training programs, including the popular Third-Age University. In addition to its educational activities, the University is also an important centre of Research and Development, with massive investment in University development and construction activities on the University campus. The University campus, in particular, is currently undergoing very dynamic changes – with an annex to the University Library building, and new buildings of the European Centre of Excellence NTIS and the Centre of Technical and Natural Science Education and Research literally growing in front of our eyes. These investments are the largest in the history of the University of West Bohemia in Pilsen and, in the future, they will form a very promising base for even more intensive co-operation with universities all over the world not only in the field of Research and Development, but also in student mobilities. The newly constructed research centres will definitely strengthen the links between the University and businesses and other institutions. This is also one of the reasons why UWB scientists involved in various disciplines, as well as UWB students, win prestigious awards for their activities every year.

The University of West Bohemia in Pilsen has a significant position among universities in both the Czech Republic and Europe. This is documented by the ECTS Label (European Credit Transfer and Accumulation System designation) the University received in late 2012, which confirms that the study environment at the University of West Bohemia in Pilsen fully matches European standards. As a result, the University has officially entered the area of European tertiary education.

The Faculty of Education of UWB is the oldest and largest faculty of the University of West Bohemia in Pilsen. It was established as a branch of the Faculty of Education of Charles University in Prague. It was solemnly opened on 14 November 1948.

In 1990, the Faculty of Education became part of the newly formed University of West Bohemia. Now, around 2,000 students are studying at FPE in many types of study programs and fields. The main objective and mission of FPE in Pilsen is to provide quality education and training for teachers of all types of schools (kindergarten, primary school, secondary school and high school).

The Faculty organizes a wide range of complementary and extension courses in the framework of Lifelong Learning.

The Faculty is trying to compete in all three roles which, as part of the university, it has: in education, research and socio-cultural areas. Its primary mission is, however, training teachers, which plays (and will play) a key role in the process of enhancing the education and culture of the nation.

Staff involved in the project: Zdeňka Chocholoušková, Thomas Přibáň

2 BIODIVERSITY AND DIGITAL TECHNOLOGIES IN SCHOOL

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Abstract
This article describes the concept of biodiversity in the school context and emphasizes what students can learn about biodiversity concepts using digital technologies. Teaching about biodiversity and its conservation could be an effective means of communicating the significance of various species and ecosystems and people's dependence on ecological support systems. A three-stage nested model with four main guidelines for teaching biodiversity is outlined, recommending teaching from the species to genetic level, from the local to global (natural, social) environment, from direct to symbolic experiences, and from the affective to the ethical level. In addition, progress in digital technologies, particularly m-learning, enables students to gain experience about biodiversity using real-world and digital-world learning resources.

Keywords: biodiversity, education, teaching, guidelines, school, digital technologies

Introduction

Life on Earth most likely began some 3.5 billion years ago. Large-scale extinction of species has occurred several times since then due to natural factors such as major volcanic eruptions and comet strikes. The largest extinctions usually mark the end or the beginning of geological periods. The most recent was the Cretaceous-Tertiary large-scale extinction of over 75% of animal and plant species (Raup & Sepkoski, 1982). Some scholars also include the period starting 500,000 years ago among the periods of minor extinctions that were caused by human activity.

There is a global trend of decreasing biodiversity resulting from human society's transformation from an ecosystem into a biosphere (Kryštufek, 1999; Primack, 2010; Sinclair et al., 2005). At the same time, there is an increasing awareness of the significance of biodiversity conservation for the survival of humankind (MEA, 2005). According to reports on the current state of biodiversity, the most negative impact on biodiversity is caused by the following human activities: the degradation and fragmentation of species' habitats, introduction of invasive alien species, pollution, excessive use of natural resources, and climate change (Hamble & Canney, 2013). Biodiversity has become a priority of the UN Decade of Education for Sustainable Development 2005–2014 (UNESCO, 2005). Governments and other stakeholders have agreed to integrate biodiversity into all levels of education (UNEP/CBD/COP/8/14, 2006). EU member states have defined the establishment of the Natura 2000 network and its effective management as a key objective for halting the decrease in biodiversity. The Natura 2000 network includes over a third of Slovenia's territory, which is important for the conservation of the species and habitats specified in the Directive on the Conservation of Wild Birds (1979) and the Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (1992), as well as endemic and nationally endangered species. The greatest current achievement of biodiversity conservation efforts has been the UN decision to declare the 2011–2020 period the United Nations Decade on Biodiversity, the main goal of which is to significantly reduce global biodiversity loss (UNGA, 2011).

The article continues by defining the term *biodiversity*, after which it discusses in detail the significance of incorporating this topic in educational processes, and presents the relevant research findings and guidelines for teaching biodiversity. It concludes by highlighting the research findings on the role of technologies in teaching biodiversity.

Biodiversity and What It Means

Wilson was the first to use the term *biodiversity* in his book of the same name (*Biodiversity*, 1988), even though it was actually coined by Rosen that same year (Lindemann-Matthies et al., 2011). Anko (2000) explains that the term is by no means new in the natural sciences. It is believed to have become fashionable after the UN Conference on Environment and Development, which took place in Rio de Janeiro in 1992. Biodiversity conservation became an important value, which was recognized as a global interest by 150 countries in 1992, leading to the adoption of the Convention on Biological Diversity.

Levels of Biodiversity
Biodiversity refers to the diversity of life on Earth, which continues to change and adapt due to ecological and evolutionary processes. In the most simplified terms, biodiversity is defined as genetic, species, and ecosystem diversity, which also agrees with the definition in the Convention on Biological Diversity. In a narrow sense, the concept of biodiversity denotes the variability among organisms in a specific region. Biodiversity implies a perfect diversity of living organisms at the level of (a) genomes, (b) individuals (in different life strategies), (c) populations, different ecotypes, and subspecies, (d) species (species biodiversity), communities, ecosystems, and different reactions of a community as a whole to the environment, and (e) biomes (Tome, 2006). Individual levels of biodiversity are presented in detail below (Primack, 2010; Sinclair et al., 2005; Tome, 2006).

Diversity within Species
A genome is the genetic material of an individual organism. The next level is the level of an individual represented by any specimen of a particular species that has unique abilities conditioned by its genetic makeup and the environment. The highest level of species diversity is the population and subspecies level. A population consists of the entire group of organisms of a given species that lives in a geographically defined location at a specific time. Animal species can be further divided into subspecies, and plants and fungi into even smaller classification categories.

Diversity among Species
It is not easy to provide a definition of *species*. At best, it can be defined as a group of organisms that can reproduce among themselves, have fertile offspring, and are reproductively isolated from other species. Diversity among species can be defined as wealth in species and species diversity, in which wealth in species refers to the number of different species in a community, and species diversity denotes wealth in species taking into account the abundance of an individual species (i.e., uniform representation of species) in a community.

Diversity of Ecosystems
Diversity of ecosystems is reflected at the level of communities, ecosystems, and biomes. The level of a community comprises all interactions between the populations of species that occupy a specific location at a specific time. The level of an ecosystem refers to the system of interconnected elements formed by interactions between a community and the nonliving environment. The level of a biome is represented by the community of the fauna and flora species typical of a specific geographical region.

Landscape Diversity
Especially in the past two decades, views have been presented explaining that effective biodiversity conservation also demands taking into account the landscape level of biodiversity (e.g., Forman, 1995). All organisms are linked to their living environment, which they participate in shaping and changing in one

way or another. In many environments, humans are a highly influential factor or the key species (Holling, 1992, cited in Farina, 1995). In 2000, the European Landscape Convention was adopted in Florence. Its objectives include landscape protection, management, and planning, and raising public awareness of the importance of landscapes.

The Significance of Biodiversity for Humankind

Environmental protection focuses on the conservation of ecosystems, habitats, and species, highlighting the intrinsic value of nature – that is, the value of nature in and of itself regardless of the benefits and value ascribed to it by humans. A variety of ecological, economic, ethical, spiritual, and cultural values are related to biodiversity and its conservation (Callicott, Crowder, & Mumford, 1999). The variety of values ascribed to biodiversity also indicates this concept's importance and controversy, which presents a great challenge to professionals in both nature conservation (Trombulack et al., 2004) and education (Gayford, 2000; Van Weelie & Wals, 2002). Fisher et al. (2009) argue that long ago different peoples understood and were aware of the natural conditions of ecosystems. Approximately 10,000 years ago, people were aware of the importance of the services that ecosystems provided to them because they used them in agriculture to increase productivity. They knew that deforestation caused soil erosion and water sources to dry out, which had a negative impact on extracting resources from the ecosystems. In his analysis of the work *Die Ehre deß Hertzogthums Crain* (The Glory of the Duchy of Carniola), Svetičič (2015) reports that the author Johann Weikhard von Valvasor comprehensively identified the production, ecological, and social functions of forests, which testifies to his broad understanding of forests. However, because Valvasor stood out intellectually in the environment of his time, his awareness cannot be equated with how society in general in the second half of the 17th century understood forests. The functioning of ecosystems as service providers was first described in the 1970 *Report of the Study of Critical Environmental Problems* (Fisher, 2009). Over the years, the terms referring to ecosystem services continued to change until Ehrlich and Ehrlich introduced the term *ecosystem services* in 1981 (Fisher, 2009). Ecosystem services were defined as various direct or indirect benefits of ecosystem processes (Costanza et al., 1997; Daily, 1997). Alarming environmental changes stimulated scientists to start systematically publicly promoting the services that biodiversity also provides to humans. However, even though ecosystems provide a multitude of various services, these are not considered in political and economic decisions because their market value is not specified or, in other words, it is difficult to specify and measure (Ninan & Inoue, 2013).

The most frequently used classification of ecosystem services is the one provided in the Millennium Ecosystem Assessment (MEA), which divides them into regulating, provisioning, cultural, and supporting services (MEA, 2005). Provisioning services are the goods produced or supplied by ecosystems (e.g., food, fiber, fuel, various medicines, genetic resources, and drinking water). Regulating ecosystem services refer to the benefits obtained from the ecosystems' regulating ability (e.g., air quality, climate, water, disease, and erosion regulation, pollination, etc.). Cultural ecosystem services comprise the nonmaterial benefits obtained from ecosystems (e.g., recreation and tourism, cultural diversity, education, aesthetic, spiritual, and religious values, etc.). The most important group is the supporting ecosystem services, which are necessary for the production of all other services (e.g., soil formation, primary production, photosynthesis, nutrient cycling, and water cycling). They also differ from other ecosystem services in that their impact on people is either indirect or occurs over a very long time, whereas other groups of ecosystem services usually have a direct and short-term effect on people (MEA, 2005).

In recent years, several studies have used ecosystem services as the basis for discussing people's attitudes towards various ecosystems (e.g., Bartczak & Metelska-Szaniawska, 2015; Gao, Ouyang, Zheng, & Bluemling, 2013; Lindemann-Matthies et al., 2014; Torkar, Verlič, & Vilhar, 2014; Torkar, 2016). Torkar et al. (2014) examined the views on forest ecosystem services held by secondary-school students in northwestern Slovenia. Supporting services were the ones that the students valued the most, especially in terms of forests providing a habitat for plants and animals. They also highly ranked regulating ecosystem services, especially in terms of clean air. Students most often visit forests due to the cultural services they provide, such as walks, recreation, and relaxation, and also for provisioning services, such as picking mushrooms and gathering firewood.

Biodiversity Education

Van Weelie and Wals (2002) argue that biodiversity is an abstract and complex concept that teachers only tend to cover at the level of species diversity because it is so demanding. Barney, Mintzes, and Yen (2005) emphasize the importance of teaching species diversity for raising public awareness of the significance of nature conservation. Hence it can be concluded that class instruction should dedicate suitable attention to learning about species and their habitats in order to address the goals of biodiversity conservation. Lindemann-Matthies et al. (2017) investigated how well prepared student teachers are to implement species identification in school. They emphasized the crucial role of the initial teacher preparation system in familiarizing graduate students with local organisms, and with suitable approaches on how to carry out species identification later in school. The authors concluded that in times of an increasing loss of biodiversity it is important for teachers to be able to familiarize their pupils with species. They are convinced that qualified teachers should at least be familiar with common wild plants and animals in their neighborhood in order to understand and teach the nature of biodiversity.

High-quality interdisciplinary knowledge is an important precondition for students to understand biodiversity and its conservation in its fullest sense and scope. Students must have a background in ecology, genetics, evolution, systemic approaches, physical geography, and other natural and social sciences. Therefore, the foundations for building their knowledge and understanding of the concept of biodiversity must already be laid in early natural science education. In their empirical study, Helldén and Helldén (2008) confirmed the significance of direct experience of biodiversity in early childhood for developing the understanding of this complex topic later on. They conclude that it is important to give children these experiences and to take their ideas into consideration in teaching for a sustainable future. Even though many researchers, including the author, highlight the significance of direct outdoor experience, the trend of decreasing outdoor activities among children and adolescents is continuing in many EU countries and beyond, especially in urban environments. It is therefore important to emphasize once again the role of direct outdoor experience, especially while growing up. According to Kellert (2002), distinguishing between children's direct, indirect, and symbolic experience of natural systems and processes forms a logical starting point in considering the childhood development of attitudes towards nature. He defines direct experience as children's direct, physical contact with pristine natural environments, flora, and fauna, where no human impact can be observed and there are no elements of the manmade environment. Children's direct experience is viewed as largely unstructured and unplanned (e.g., free outdoor play). Kellert includes structured educational programs and activities in the category of indirect experience, which involves a more planned, organized, and structured learning context (e.g., children's experiences of animals, plants, and habitats at zoos, aquariums, botanical gardens, arboretums, natural history and science museums, etc.). The last group of experience defined by Kellert is symbolic experience, which occurs in the absence of children's physical contact with natural environments, flora, and fauna. Children encounter various forms of representations of nature conveyed as pictures, models, metaphors, analogies, symbols, myths, legends, films, and so on.

Based on his empirical study, Kellert (1985) also identified three stages in the development of children's perception of animals. The first transition is between ages six and nine, when changes in children's perception of animals primarily occur at the emotional level. This is followed by a transition between ages 10 and 13, when the cognitive level or knowledge and understanding of animals increases. The last transition occurs between ages 13 and 16, when increased attention is dedicated to ethical concerns and the ecological importance of animals and the natural environment in general. Based on this and other studies, Kellert (2002) designed a three-stage model of the development of attitudes towards nature in children and adolescents, which shows a transition from the initially utilitarian and dominionistic attitudes, via aesthetic, humanistic, symbolic, and scientistic attitudes, to moralistic and ecological attitudes. This transition of attitudes to nature is captured well also in the pedagogy of Joseph Bharat Cornell, who suggests in his book, Sharing Nature with Children (1979) the Flow Learning Model of four stages: Awaken Enthusiasm, Focus Attention, Direct Experience, and Share Inspiration. In the initial stage of the model children learn if the subject matter is meaningful, useful, fun, or in some way engages their emotions. Next stage challenges children to concentrate on some of their physical senses to be more calm, observant and receptive of the surrounding. This enables children to deeply experience nature in the third stage. These experiential activities have a dramatic impact that involves children directly with nature. And the last stage provides children with the time to reflect upon an experience that can strengthen and deepen that experience.

Müller, Kals, and Pansa (2009) studied nature-friendly behavior in 15- and 19-year-olds and determined that emotional affinity towards nature and indignation over the poor condition of the natural environment are important predictors of nature-friendly behavior. Chawla (2009) argues that nature-friendly behavior can also be motivated by empathy and sympathy, in which she relies on Hoffman's theory of empathic morality (2000). According to this theory, empathy and sympathy form the basis for developing prosocial actions, which Chawla extends to children's encounters with animals and other living beings.

McInerney, Smyth, and Down (2011) also highlight the importance of schools forming connections with their local environment in order to improve student engagement and participation in the local community. This creates opportunities for young people to learn about and care for the wellbeing of the community they belong to. Lindemann-Matthies et al. (2011) argue that social connections with the local environment can comprise both the inclusion of locals (various experts) in the class activities and the students' investigation of environmental issues directly in the local community. In addition to this, greater importance should be ascribed to various local organizations (e.g., environmental and nature protection organizations) that can use their expertise and experience to contribute significantly to higher-quality biodiversity education in schools.

During the first six years of primary school, it is especially vital for teachers to focus on biodiversity at the level of species and their habitats. It is important for students to learn about the local natural environments and examples of the protected and endangered species living there (e.g., Proteus in karst caves and the snake's head lily in the wet meadows). Only then should they start exploring remote and exotic ecosystems, and the issues revolving around the conservation of polar bears and the tropical rain forest. Various studies, including a Slovenian one carried out in 2016 by Torkar and Mavrič, have shown that students do not know much about the fauna of their local ecosystems. They are most familiar with the exotic animals in Africa. Ecosystem and genetic biodiversity is more demanding to understand and therefore it is vital to cover it together with genetics and ecology—that is, in science or biology classes in the final years of primary school and in secondary school.

Figure 1 summarizes the main guidelines for teaching biodiversity and its conservation. The four major guidelines recommend teaching: (a) from species to genetic diversity, (b) from local to global (natural, social) environment, (c) from direct to symbolic experience, and (d) from the affective to ethical (moral) considerations. The color of the bulletins and frames used refers to three nested stages: where to begin (blue), continue (green), and end (orange) basic biodiversity education in schools. While progressing from first to third stage frames are more inclusive – including prior stage(s) and new stage of biodiversity education (complexity of issues increases).

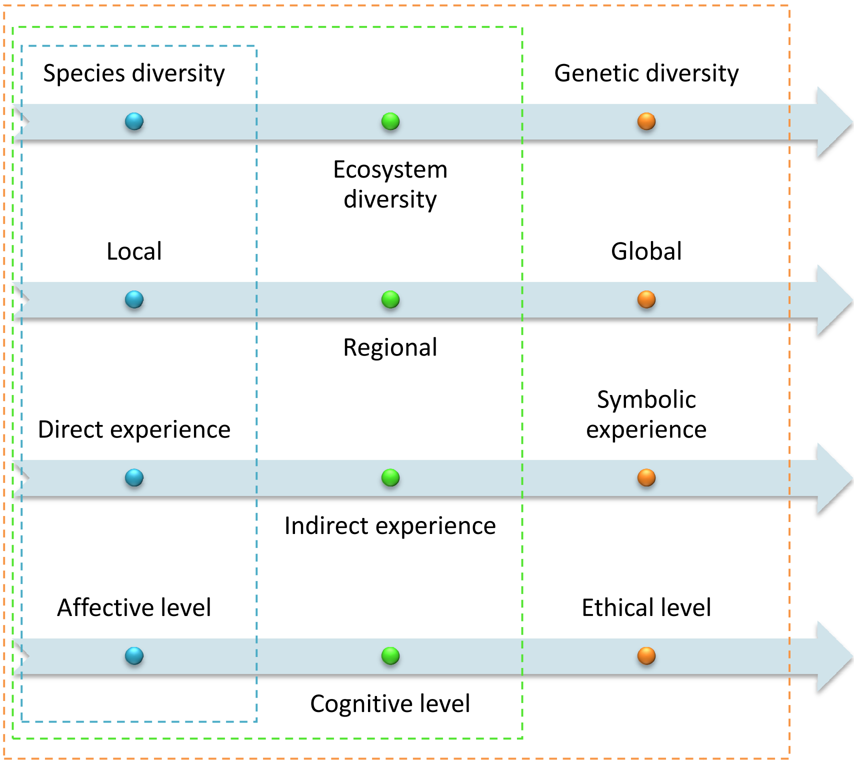

Figure 1. A three-stage nested model of four guidelines for in-depth biodiversity education.

The Role of Digital Technologies in Biodiversity Education

Educational technologies have greatly transformed the outcomes of the teaching and learning experience in classrooms (Chen et al., 2008; Kubiatko & Haláková, 2009). The use of mobile learning (m-learning) in education and training has proved useful in several studies (Ahmed & Parsons, 2013; Chinyamurindi & Louw, 2010; Chu et al., 2010; Farrokhnia & Esmailpour, 2010; Huang et al., 2010; Kamarainen et al., 2013; Rogers et al., 2010). It has also been shown to successfully bridge the gap between school-specific digital tools and everyday digital tools, as well as between formal and informal learning (Rau et al., 2008; Santos et al., 2014). The advantages, disadvantages, and opportunities for using these tools were reviewed by Cheon et al. (2012), and Perbawaningsih (2013). The most important advantages are further opportunities for outdoor learning, improving collaboration among users, and the motivational effect of working with apps. Among the disadvantages that researchers mentioned were limited storage, battery capacities, and problems with signal strength.

M-learning has several definitions (Keskin & Metcalf, 2011; Ong & Lai, 2006; Ozdamli & Cavus, 2011; Ozuorcun & Tabak, 2012). It is similar to e-learning, but it is unique in terms of flexibility of time and location (Chen et al., 2008; Peters, 2007). It requires mobile phones or mobile (tablet) computers, which are now common among students and the general public. They can be used to access learning materials or required information, to collaborate, or to discuss material anytime, with anybody, anywhere (Gikas & Grant, 2013; Keskin & Metcalf, 2011; Lee, 2013; Ozdamli & Cavus, 2011; Ozuorcun & Tabak, 2012; Perbawaningsih, 2013; Peters, 2007). Similarly important are advanced hardware for these devices (e.g., cameras, accelerometers, etc.) and applications (see Ahmed & Parsons, 2013) that broaden the possible spectrum for teaching and learning (Chen et al., 2008; Keskin & Metcalf, 2011; Peters, 2007).

The use of ICT is traditionally seen as antagonistic to experiential learning in nature, especially because it has so far kept participants from directly experiencing the natural environment (Shultis, 2001).

Learning only in virtual environments is partly responsible for alienation from nature (Van Velsor, 2004) because simulations and presentations cannot replace the comprehensive experiences that can be obtained in natural environments (Evans et al., 2007; Patrick & Tunnicliffe, 2011; Prokop et al., 2007; Spicer & Stratford, 2001). In many countries the general public has a low level of awareness about local environmental issues, a poor understanding of ecosystems, and a general lack of care and apathy towards the environment (Evans et al., 2007). On the other hand, appropriate use of computers and ICT can improve attitudes towards biology and the natural sciences (Fančovičová & Prokop, 2008; Kubiatko & Haláková, 2009; Soyibo & Hudson, 2000) and can improve the quality of biology and biodiversity education (El Asli et al., 2012). Various apps already exist for courses on environmental science (e.g., Iancu, 2015; Kamarainen et al., 2013) and for botany courses. One example is a mobile location-aware learning system in which questions guide the students to observe and recognize features of plants on a school campus (Chu et al., 2008).

M-learning has an important advantage over traditional ICT methods. It offers digital data and apps that can be applied outside of the traditional learning environment (Chinyamurindi & Louw, 2010). This offers new learning opportunities for bridging the distance between virtual tools and experiences in nature (Ruchter et al., 2010). The use of mobile devices offers different learning experiences and different opportunities (Ahmed & Parsons, 2013; Ozdamli & Cavus, 2011; Rogers et al., 2010) that can help pair the benefits of computer-mediated digital learning with direct experiences in the natural environment (Ruchter et al., 2010). The combination of active, participatory, and collaborative learning methods and outdoor experiences results in improved biodiversity knowledge and attitudes (Fančovičová & Prokop, 2011; Kamarainen et al., 2013; Laganis et al., 2017; Rogers et al., 2005; Schaal et al., 2012). For example, Laganis et al. (2017) found that identification of plants with an app proved to be successful in promoting learning about plants. Students accepted an app on a mobile (tablet) computer very well. It has proven to be an effective, interesting, and convenient learning tool for identifying organisms that allows experiential learning and learning about biology during the identification process.

Through the combination of real-world and digital-world learning resources (Chu et al., 2010; Rogers et al., 2005; Vogel et al., 2010), learning can become active, more like continuous research than memorizing a body of facts (Kubiatko & Haláková, 2009; Lee, 2013). It can successfully introduce students to scientific thinking (Ahmed & Parsons, 2013) and improve scientific literacy (Patrick & Tunnicliffe, 2011). Biology courses become more attractive, and they result in students significantly improving their knowledge of plants and their attitudes toward them (Fančovičová & Prokop, 2011; Huang et al., 2010; Rogers et al., 2005).

Conclusion

For the majority of people, naming, for example, 100 species of animals is far from a trivial task. This demonstrates well what the real (social) interest in nonhuman entities is, because the estimated total number of eukaryote species on Earth is over 8,000,000 (Mora et al., 2011). Biodiversity education is much more than just teaching and learning about nature. Biodiversity is an important element of education for sustainable development, demonstrating the interconnectedness and inseparability of the concept's ecological, economic, and social aspects, and demanding that students analyze the issue comprehensively from various perspectives (Dreyfus, Wals, & Van Weelie, 1999; Gayford, 2000), but within the ecological conditions of the environment. The progress in digital technologies described above, particularly m-learning, enables students to gain experience using real-world and digital-world learning resources, which can have a significant positive impact on the quality of biodiversity education.

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3 APPS AND BIODIVERSITY: TEACHERS USING DIGITAL LEARNING TO TEACH ABOUT BIODIVERSITY

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Introduction

The TEALEAF project which has run from 2014 until 2017 built on the SOPHIA project which took place between 2005 and 2009. The follow-on emphasised two domains: i) a continuing constructivist emphasis, and from the Irish perspective, ii) the use of computer apps in teaching junior secondary science students about ecology and specifically two ecosystems (McCloughlin, Gash, & O'Reilly, 2008, 2009; McCloughlin, O'Reilly, & Gash, 2009). The idea for the TEALEAF project was that this latter aspect could be extended to a whole project. Three of the original participants and two new partners embraced the idea of teachers designing their own learning tools. Of course, this has been done already, but to a lesser degree when the resource is digital. We also suspected that whereas there are many apps available for mathematics and physical science, the same could not be said for ecology or biodiversity. So, we needed to lay the groundwork for the project by ascertaining whether there was a deficit in digital learning (DL) resources in ecology and biodiversity in particular.

We take constructivism to mean that "knowledge is modeled as a construction made in response to experienced discrepancies between ongoing experience and past knowledge". Pupils' own activities and thoughts are central in the construction of knowledge, and teachers play important roles in helping children differentiate their initial understandings of phenomena they understand partially. The Irish – primary – National Curriculum (NCCA, 1999) – but not the secondary syllabus (NCCA, 2015) – involves at least some of the following methodologies, which have their origin in the work of Piaget and Vygotsky and updated by the cognitive acceleration model (Adey, Robertson, & Venville, 2002; Adey & Shayer, 1994) the key components of which are listed following:

- Concrete preparation: Students require a basic experience in unfamiliar objects and events so that novelty does not detract them from the learning experience.
- Socratic irony: When the teacher feigns not knowing the answer to a problem or question in a dialogue.
- Utilising prior knowledge: Tools to determine what students know already.
- Cognitive conflict: Generating and sustaining episodes where the students experience 'dissonance' when their experience – and interpretation – does not match their observation or the teacher's explanation.
- Social construction: Allowing the students to have the opportunity to discuss the practical/results in small groups.
- Meta-cognition: Allowing the students to have a role in deciding the structure of a lesson and thinking about their own thinking.
- Bridging the lesson between the classroom and everyday life.

For the Irish team, the constructivist emphases were:

1. Emphasis on dialogue – social construction – as a means of constructing shared meaning. On closer examination, we see that the methodologies can involve dialogue as a key component and this is an important vehicle for most, if not all, the methodologies.

2. Emphasis on teachers' selfexamination of practice and values, and the effects of engaging with the lessons having to deal with a possible alternative mode of practice.

The Role of Digital Learning

The use of digital learning environments involving technologies such as Flash games, simulations or applications or simply 'apps' has received much attention in the educational world. Many are quite sophisticated environments where the user is enveloped in an alternative world and often engages with a virtual or alternative reality. These digital learning environments may be best suited to single computer users. Notwithstanding, changing the standpoint of practicing teachers can be difficult. Thus, we note a conflict between catering for the needs of the child, i.e., learning, and we emphasise 'meaningful learning' (Marcou & Valanides, 2006) and catering for the needs of the teacher, i.e., change of practice – very often the teacher is as unwilling to change her practice as past practice seemed effective (Meletiou-Mavrotheris & Mavrotheris, 2006). The difficulty of changing teaching practices in digital learning is described by.

> We attempted to incorporate digital learning of biodiversity into the wholeclass setting. Dendrinos (2005) noted that more than 10 years ago teachers seldom used computers available in schools on account of the lack of technical support (INTO & CESI, 2007). However, we suspected that there were fewer resources available for learning concepts associated with biodiversity, however there are some notable exceptions. It was difficult to analyse this on a Europe-wide analysis because of the variety of languages.

Teachers are more likely to incorporate digital learning into their classroom practice if they feel 'comfortable' with it. Minimal changes facilitate such comfort, thus it would be anticipated that further change could be encouraged gently and be allowed to 'creep in.' To help with this scenario, the forms of digital learning must be simple and not require a high level of technical capability.

Thus, we probed the participating teachers in each country for their experiences of digital learning in science. We had a hypothesis that when it comes to learning about biology, there is a general trend not to use digital learning. We also needed to know the source of this lack. So, we asked ourselves a number of questions:

Problem 1. What do teachers use for their digital learning approaches in school?

This involved a survey of possible uses based on the consortium members' own experience of teaching using digital tools, in order to assess whether there a European dimension to this question. In Ireland, at least, there has been a huge investment in the procurement of interactive whiteboards in classrooms, and the question is whether trend this is widespread, and whether experienced teachers use them.

Problem 2. Is there a disciplinary imbalance in the use of apps in science? It has been suggested that Mathematics and Physics have the greatest emphasis in app development due to the perceived difficulty of these subjects. However, we suspect that the real picture is more complicated than this, and furthermore detailed work will be required to understand this issue. Before we examine these results closely, the samples will be outlined. Of the five countries participating in the TEALEAF project, there was a sample of 234 teachers across all subject domains of which 27% were male, and 67.3% were female, and 5.6% not given or incomplete. The samples were convenience and volunteers were recruited by email, word-of-mouth, letter, poster, newspaper notice. The questionnaire was administered in paper and electronic form and including some background items there were 50 questions. The electronic version took five minutes to complete. The substantial questions examined the technologies teachers used, how apps are used if at all, the barriers to using apps, and the frequency of use of apps. The general parameters of the samples are listed in Table 1. where we note the majority, i.e., >50% category in each sample. Figure 1 provides a view of the overall spread of educational domains involved in the study.

Table 1. *General parameters of the samples*

Country	Proportion of sample, %	Majority of teachers' experience, years	Majority of teachers' domain	Majority taken CPD technology & science
Czech Republic	15	>15	secondary	yes
France	22.2	>15	primary	no
Ireland	22.2	>15	primary	no
Slovenia	19.7	>15	primary / secondary	yes
Spain	20.9	11-15	secondary	yes

The majority of teachers in the sample had considerable experience, and in three countries had taken a Continuing Professional Development (CPD) course in using digital technology in teaching science – often these were secondary teachers.

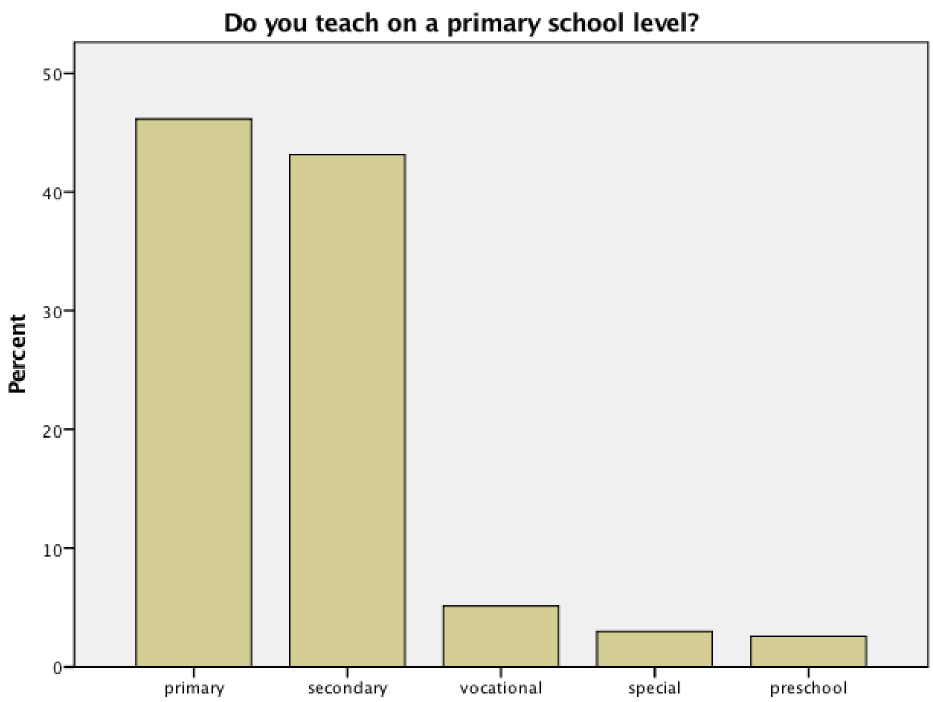

Figure 1. Percent of the cohort by educational domains involved in the study

Results

One of the important ideas in the TEALEAF project is the use of apps in learning about biodiversity, but first we need to see if teachers teach about biodiversity regardless of the method. Figure 2 represents a snapshot and Ireland stands out as having a large proportion of teachers who 'almost never' teach the concept biodiversity. Clearly then, whether they use apps to do so is moot. The responses "seldom" and "often" – depending of what these mean to the individual teachers – are represented well in the dataset.

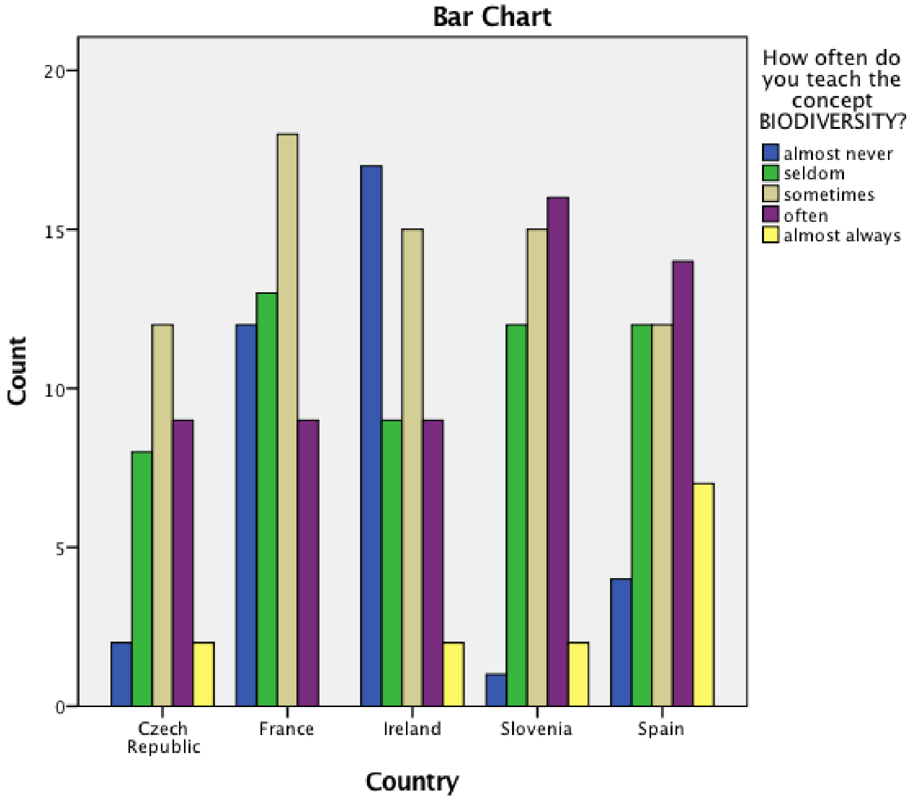

Figure 2. How often teachers teach the concept biodiversity

An overall view of the dataset is presented in Figure 3. In Figure 3 a problem is of course where combinations of technologies exist, and these are not reflected in the questions to the teachers, but are perhaps reflected though not discernable in the answers they gave. All the countries had representation in each of the usage categories, and no one country absolutely lacked or excelled in takeup in any of the categories. Curiously, we were aware teaching the concept of "ecosystem" was treated differently, and it is our feeling that more work needs to be done to determine the level of teachers' understanding of biodiversity *qua* ecology. We suspect that ecology or ecosystem is often assumed to be about the animals which live in a particular habitat as opposed to the relationships between them. In spite of this, the concept of invasive species is rarely taught whereas environmental protection is addressed by all countries quite often. It seems that teachers prefer to speak about issues rather than specific scientific detail, however, this might indicate a worrying aspect where teachers teach about issues on conservation without encouraging any real strategies in relation to local environmental issues.

In addition to the descriptive analysis outlined , we also subjected the data to multidimensional scaling(MDS) (Borgatti, 1997; de Leeuw & Heiser, 1980; T. McCloughlin, 2015; T. J. J. McCloughlin, 2015) which permits us to examine the commonality of the groups of teachers in each country, that is the extent to which they answer questions with similar patterns (Alt, 2015; Ding, 2015; Jaworska & Chupetlovska-Anastasova, 2009; Li & Sireci, 2013)

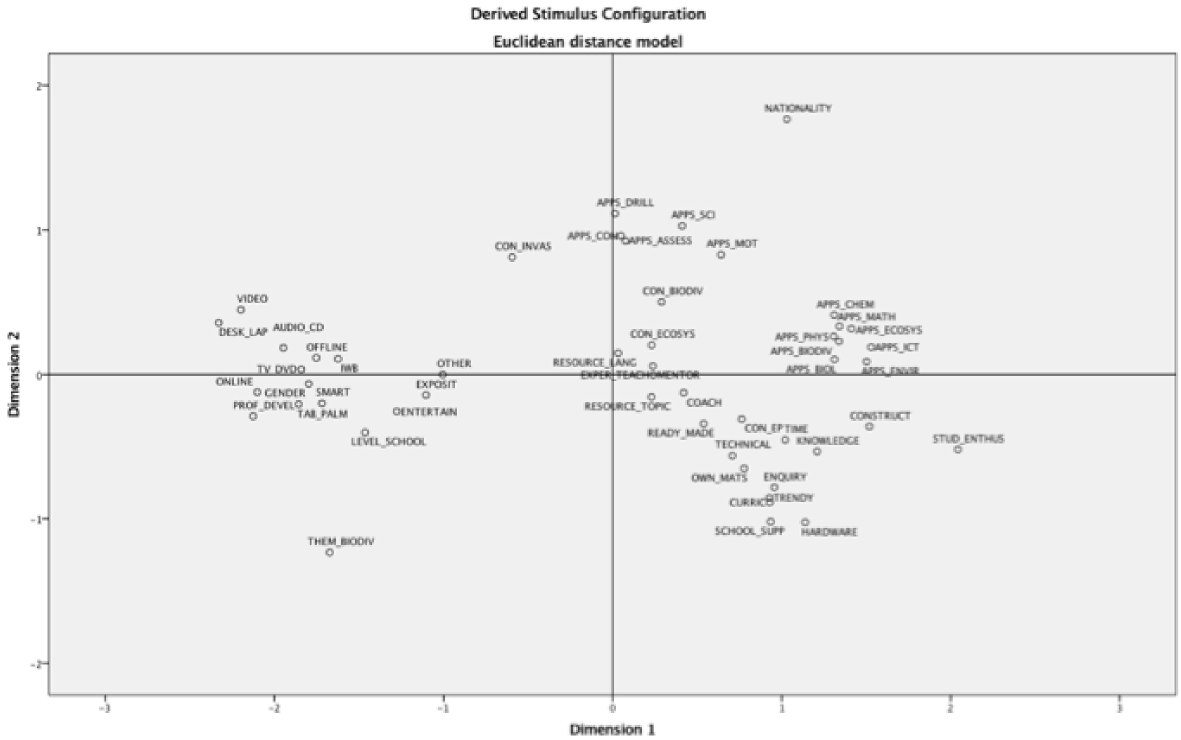

Figure 3. Derived stimulus configuration of all data

Figure 3 shows the spread of plots of "dimensions" calculated from the total questionnaire data set. The cluster on left hand side are the dichotomous questions for whether the teachers used specific technologies in their teaching of biodiversity, by gender and where they teach the theme of biodiversity – THEM_BIODIV. Tightly clustered is the GENDER, ONLINE, SMART, PROF_DEVEL elements indicating a similar set of answers to these questions: thus, being female, using online resources, perhaps on a smartphone and engaging in professional development is one deduction. Looking at the next outer layer of cluster points, DESK_LAP-tops, and VIDEO, AUDIO_CD, teaching in an EXPOSIT-ory style, and considering that apps are really considered ENTERTAIN-ment for students is a less frequent category of teacher. The tight righthand cluster concerns using apps for specific subjects, and on the face of it, because this cluster is so tightly ploted, the answers were uniform, thus teachers in general used apps occasionally for all the subjects, though we doubt there was an appropriate distinction made between biodiversity and learning about ecosystems. Finally, there is a broad swath of plots on items concerning impedance to using apps and little or no consensus was found on the various causes. So, for some, language was an issue, the level that the app was pitched at or how to bring it into an already existing scheme were important, but we only asked about language in the questionnaire.

Individual derived stimulus configurations were plotted in two dimensions for each of the countries[1], Figure 4, 5, 6, 7, 8, and 9. In each case, the plots are loose with minor clusters demonstrating that one cannot characterise what primary versus secondary teachers think about a particular idea in education and teachers generally hold a range of ideas which overlap among groups. The closer the clusters to the origin of each graph, the more uncertain their thinking, and in Slovenia, teachers were more confident of their answers, marked by plots near the origin, Figure 7, hence the appearance of a "ring" of plots. That the data appeared as a ring suggests strong differences in opinion as well as confidence in their answers. The Spanish plot, Figure 8, also assumed a ring structure but one side entered the region around the origin suggesting uncertainty in those teachers. In general, the teachers in France, Figure 5, Ireland, Figure 6, Slovenia, Figure 7, and Spain, Figure 8 all exhibited differing opinions within their own national groups. Outliers represented teachers with missing values as in the left hand side of Figure 4.

1 SPSS can only handle 100 cases for MDS, otherwise all the countries would have been included on the one graph appearing in the following, alphabetical, order: Czech Republic, France, Ireland, Slovenia, and Spain.

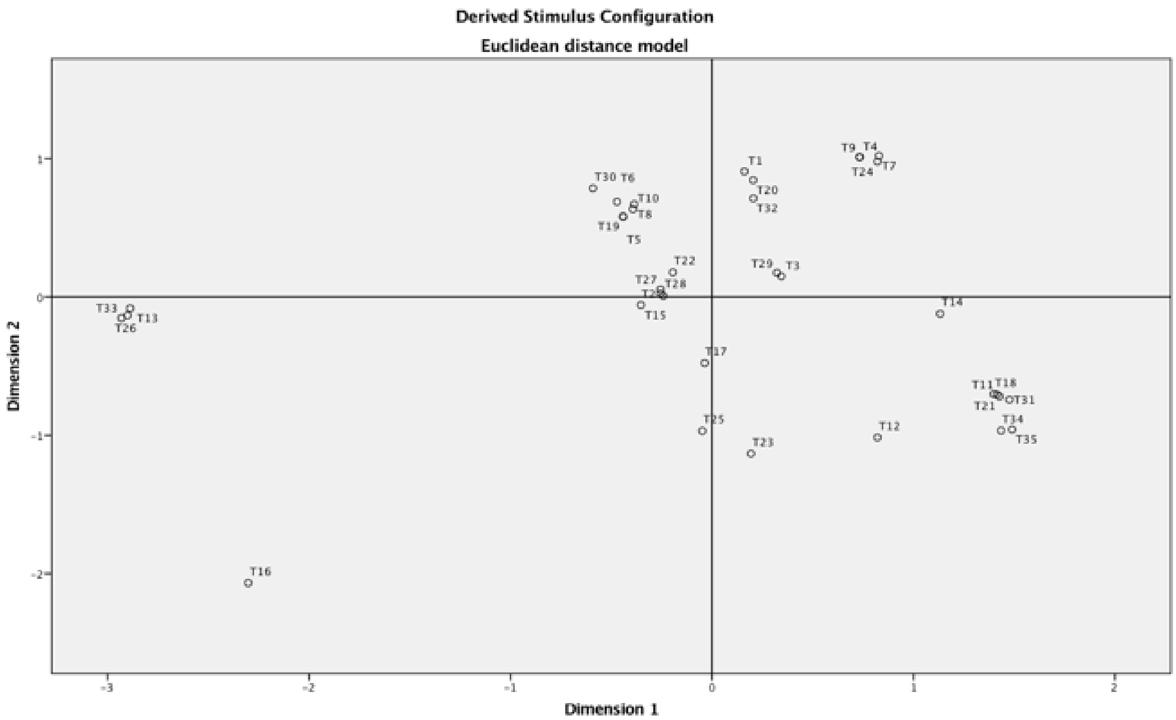

Figure 4. Derived stimulus configuration of transposed data for the Czech teachers

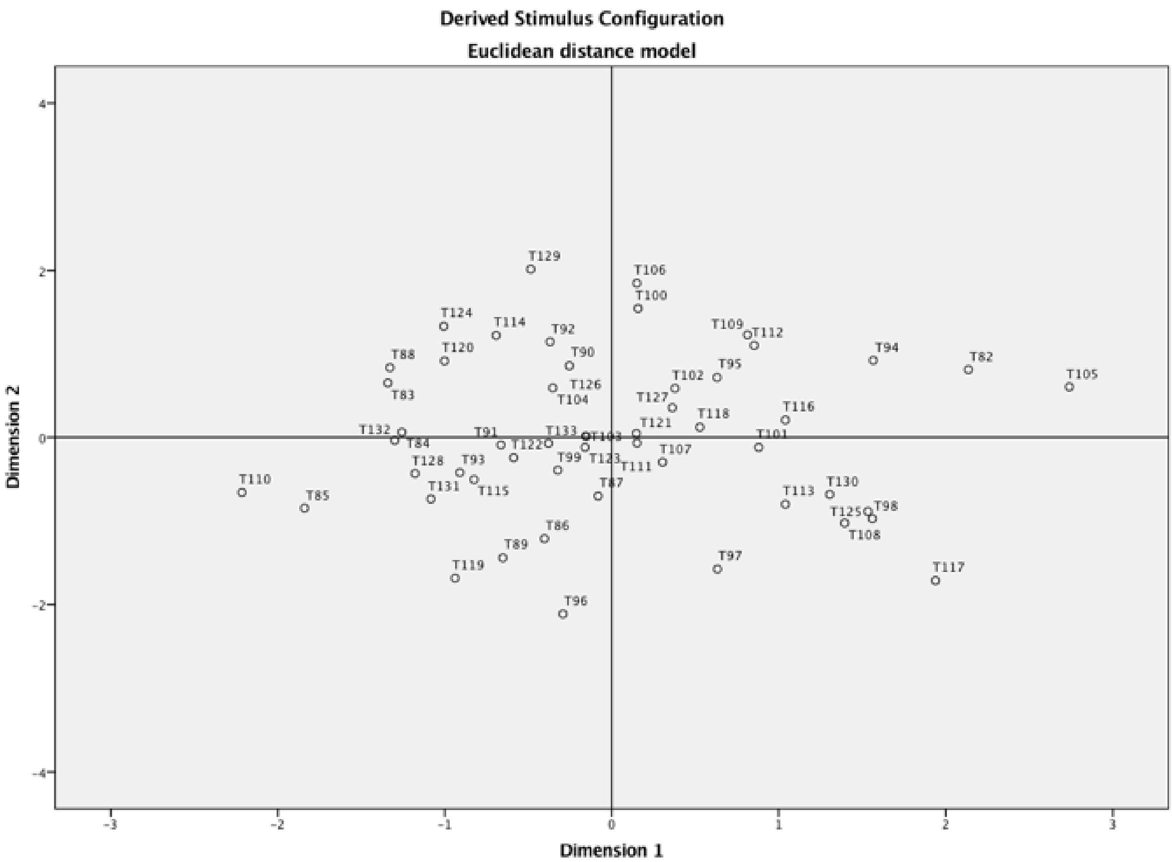

Figure 5. Derived stimulus configuration of transposed data for the French teachers

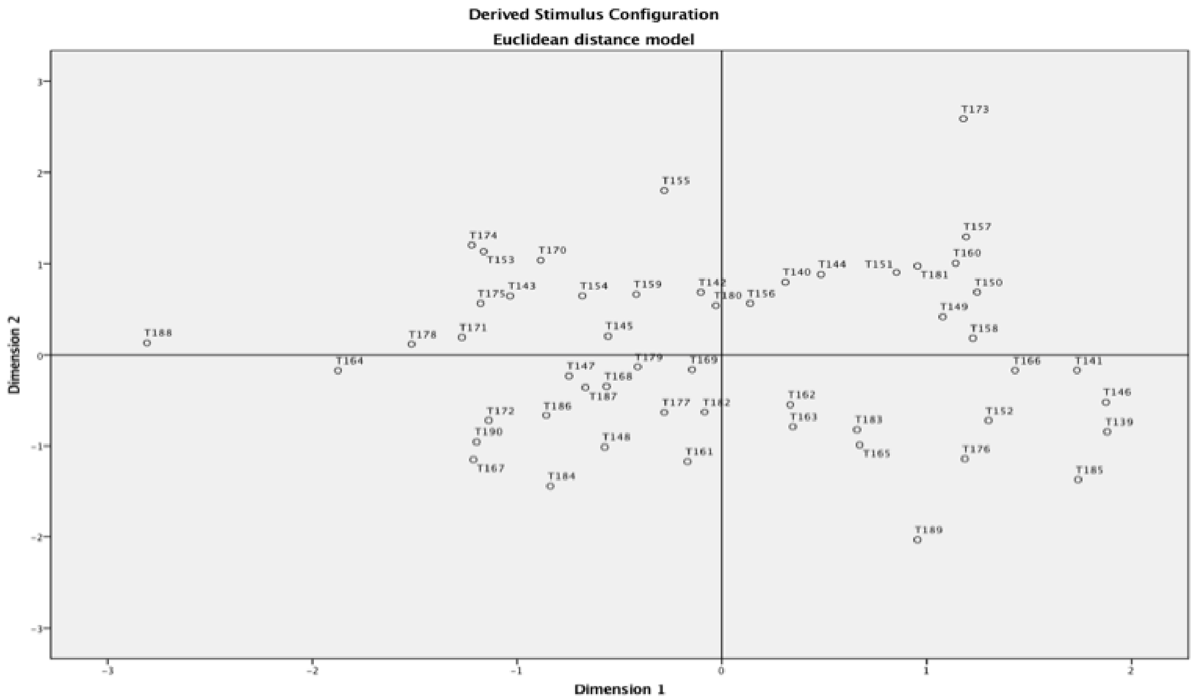

Figure 6. Derived stimulus configuration of transposed data for the Irish teachers

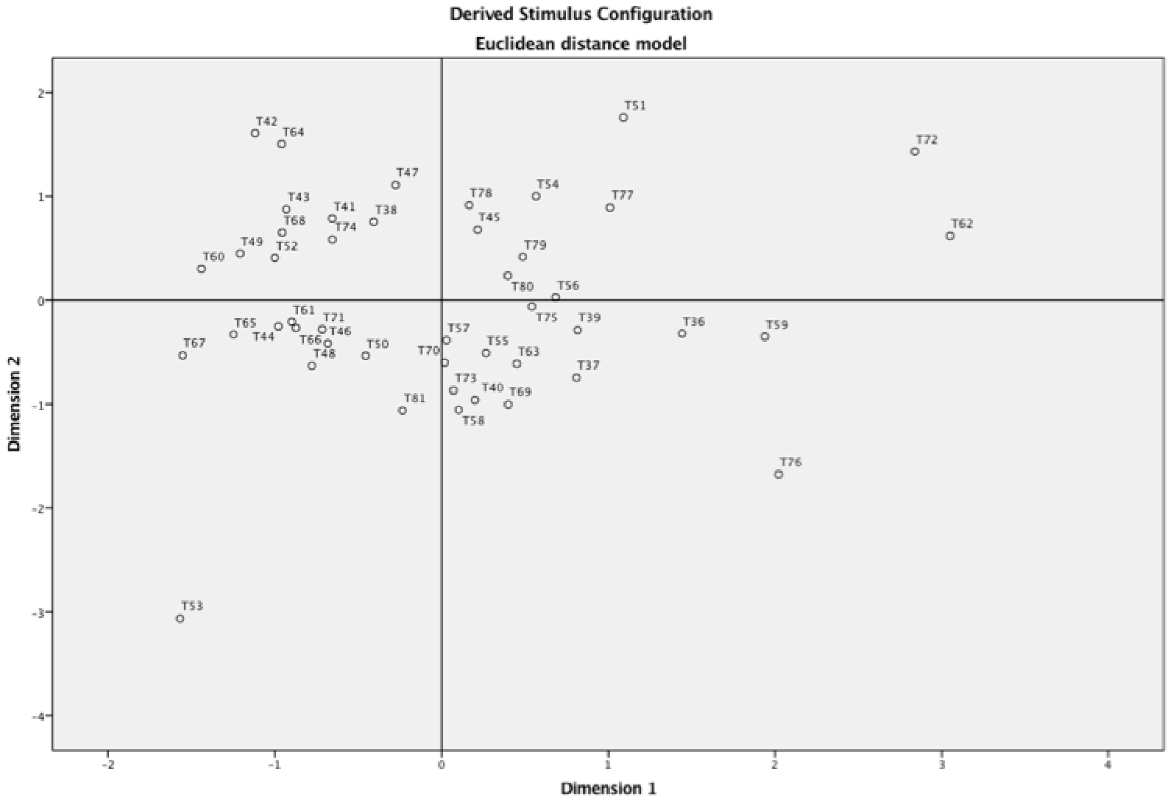

Figure 7. Derived stimulus configuration of transposed data for the Slovene teachers

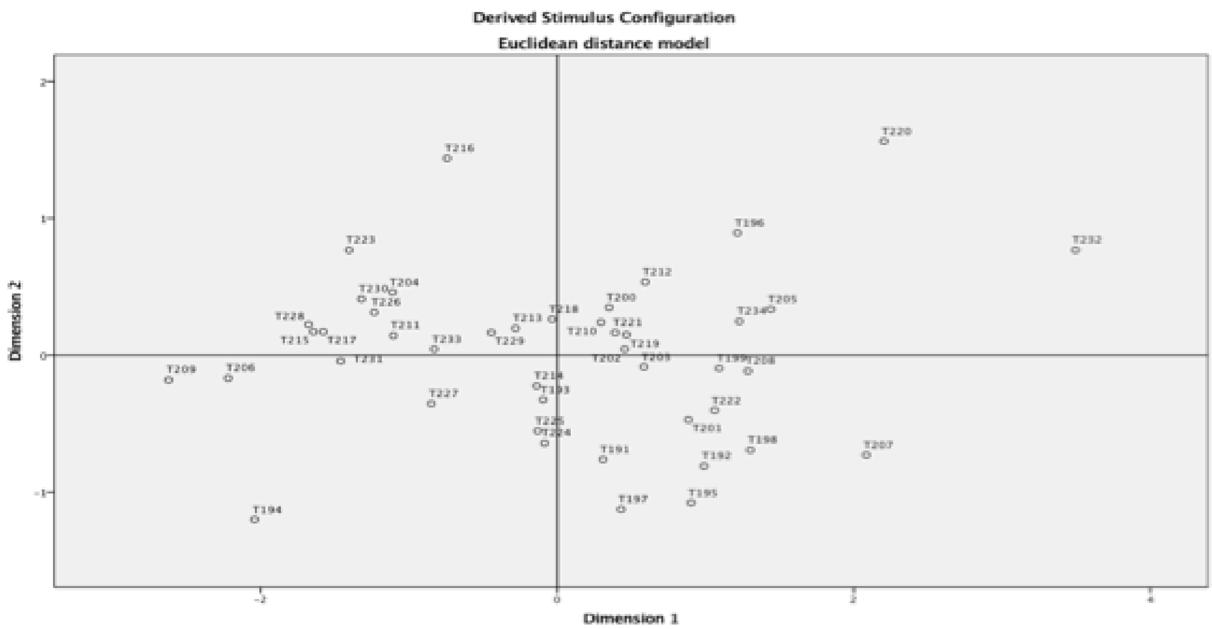

Figure 8. Derived stimulus configuration of transposed data for the Spanish teachers

Conclusion

The final approach to the data, and by way of summarising the data was to plot the data as a theoretical morphospace (Johnson, 2008; Kendall, 1984; McGhee, 2006). This is based on Sewell Wilson's original idea using this statistical technique in the early 20th century. Here, the theoretical morpohospace was based on the average answers by country for each question indicating an overall 'frequency' of response. As with multidimensional scaling (MDS), the dimensions are not required to be fully defined in reference to the actual data, however, in the TEALEAF data this is the case. Thus, we have not calculated intermediate eigenvalues as in a principal components analysis. The resulting Figure 9. is not an eigenform but rather a three-dimensional curve of the data for the whole population (Hofbauer & Sigmund, 1998).

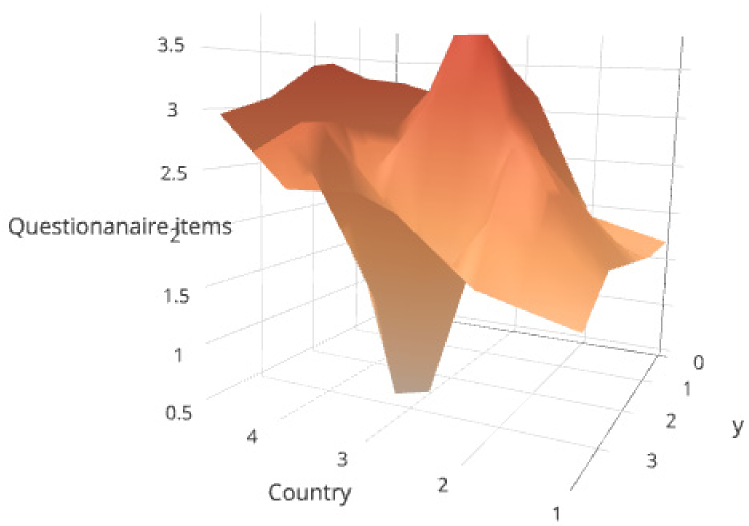

Figure 9. The TEALEAF theoretical morphospace – Country axis: 1 = Czech Rep., 2 = France, 3 = Ireland, 4 = Slovenia, 5 = Spain

The graph is best considered from the right-hand side which begins with country 1, i.e., the Czech Republic. The data appears as the foothills of a mountain resembling the data of France with a deep valley following – Ireland – to rise to low mountains – Slovenia and Spain. France and Ireland appear to stand out and for different reasons. Each had a high representation of primary teachers, but France had representation from preschool teachers also, and when one examines how they answered, the most obvious difference is that biodiversity is taught more directly than in Ireland, and there is less reluctance to engage with the use of apps to teach specific topics such as biodiversity.

These findings should frame recommendations for policymakers to engage more wholeheartedly with in-career / CPD with teachers of this age profile and not wait for those hesitant with DL to retire hoping that the younger cohort of teachers will bring into the teaching profession DL capabilities and skills. As was demonstrated later in the project, when teachers are appropriately facilitated, they show how they can do amazing things.

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4 EXISTING APPS FOR LEARNING BIODIVERSITY AT SCHOOLS

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Abstract
Using games in a learning environment can support 21st Century skill development and sup-port formal education in schools. In this paper, we present the identification and evaluation of existing apps and serious games which could be used to teach biodiversity and conservation as identified by teachers in five European countries.
Teachers were asked to select free-sourced, computer apps from the internet and determine their efficacy in meeting learning objectives. A total of 86 different apps were selected and were placed within three major groups: static digital resources (such as electronic atlases, bird sounds, etc.), interactive digital resources (simulation or quizzes), and serious games. Most apps (43%) were identified as providing pupils with the opportunity to acquire conceptual knowledge (mostly serious games), while 37% of apps had a declarative knowledge compo-nent (these were primarily static and interactive digital resources). 44% of apps identified were strategy-type and 28% were simulation. Most (41%) of the existing apps were identified as suitable from 9 to 11 years old children or 15-18 yr. olds (20.5%).
Overall, there are a wide range of free and available apps which could be used in a variety of ways to teach key learning objectives from within the scope of biology and ecology. Surpris-ingly, 57 % of the apps identified were only supported by Windows hardware. This may limit opportunities if schools focus on the purchase of tablets rather the purchase or maintenance computer hardware. Teachers need to assess the apps for themselves and determine if the app can be supported and if it is appropriate for their particular class.

Keywords: existing apps, Tealeaf, content, learning objectives, curriculum, knowledge, serious games, digital resources

Introduction

Within their everyday practice, today's teachers commonly use some form of computer engagement such as; on-line class books, schedules, or e-communication with students to help meet their school agenda. Although these may be effective organizational tools, other digital resources exist that can be used to further enhance teaching and learning within the classroom.

Over the past ten years, European schools have been equipped with data processing hardware such as computers, tablets and smart boards (Chocholoušková & Přibáň, 2016). Within this same time-frame, a variety of commercial computer games, intended for educational purposes, has been produced. Many of these 'serious' games are freely available on the internet and are developed for a variety of media, including online gaming (Yusoff et al., 2009). Learning using serious games is not a didactic process and instead, occurs when the player actually plays the game (Siang & Rao, 2003). Learners must discover and then transform complex information, incorporate new information and modify their understanding as they play. This discovery-based approach to learning fits well within a constructivist pedagogy (Siang & Rao, 2003; Tsai, F. H., Yu, K. C. & Hsiao, 2007). Serious games can be designed to have specific learning outcomes, which involve both the development of the player's capability within the framework of the game (cognitive, psychomotor and affective skills) and the instructional content or specific subject matter of the game (Yusoff et al., 2009). Using games in a learning environment can support 21st Century skill development and serious games are used in training settings for public employees (Buendía-García et al., 2013) and supporting formal education in grade schools (Ilicsak & Wright, 2010) and within higher educational settings (Bekebrede & Mayer, 2011).

TeaLeaf was designed to enhance the teaching of biodiversity through the use and development of serious games. It involved around 100 teachers from five countries (Czech Republic, France, Ireland, Slovenia and Spain, about 20 teachers from each country). The first phase, which is reported here, involved the mapping of existing computer applications, which teachers could use in their educational process.

Methodology

Participating teacher from each country were asked to search the internet and identify games or apps that would address biodiversity and conservation, (in-line with their countries curriculum requirements). Teachers were then asked to evaluate these apps and fill out the provided template. Teachers were asked to identify the requirements associated with the app, how the app was to be used, what learning objectives could be achieved by using the app and what was the most appropriate age group. Each country uploaded their forms on the common website, and a list of apps and serious games, along with web link, were compiled (Appendix A).

Results

A total of 86 apps were identified from the teachers' internet search. These apps could be placed within three major groups: static digital resources, interactive digital resources, and serious games.

Static digital resources
These apps provide specific content information. Teachers could show or students could access the various types of organism, events, videos, images, animations, etc. to gain knowledge. Additionally, these resources could be used as a trigger for discussion or investigations. (Table 1).

Table 1: *Examples of Static Digital Resources*

Name	Link
Botanical photogallery	http://botany.cz/en/
Encyclopaedia Britannica	www.britannica.com
Czech web about insects	http://www.hmyz.net/

Interactive digital resources
The second group is applications which allow teachers to create and develop learning tools, such as; crossword puzzles, simulations, etc. These can be used within lessons as a learning or assessment tool (Table 2).

Table 2: *Examples of Interactive Digital Resources*

Name	Link	Genre
Ihuerting	https://itunes.apple.com/es/app/ihuerting/id464683669?mt=8	simulation
Food chains and webs	http://www.sheppardsoftware.com/content/animals/kidscorner/games/foodchaingame.html	simulation
Photosynthesis	http://www.biomanbio.com/GamesandLabs/PhotoRespgames/phorespgame.html	push-pull

The third group contains the serious games. These resources increase educational potential, encouraging students to increase their abilities to analysis, synthesis, and problem solve. This type of app encouraged creativity within student learning as they construct their knowledge through the mastering of the game (Table 3). Teachers prefer to use smaller games and different online resources, and avoided massive online games. One teacher commented that they would be concerned over student safety if students were allowed to game in an online setting.

Table 3: *Examples of Serious Games*

Name	Link	Genre
EcosysGame	http://ecosysgame.fr/index.html	strategy
Bioman	http://www.biomanbio.com/GamesandLabs/PhotoRespgames/phorespgame.html	strategy
Extinct - plant survival game	http://www.bbsrc.ac.uk/bbsrc/cache/file/277CD3E7-6173-4352-931C3364FA5CED83.swf	real play game

Capability – Apps genre

The genre is the type or category of the game and has implications for the capabilities developed through playing the game (Yusoff et al. 2009). We identified existing apps into various genres: arcade game, real player game, strategy, push-pull, massive online, beat-'em-up, chase, sandbox, simulation and other. These different categories provide students with different learning experiences and encourage different cognitive development (Siang & Rao, 2003).

Most of the apps identified fell within the 'strategy' genre (44%) with 'simulation' being the next most common (28%). The rest of the genres were not strongly represented in the sample collected by the participating teachers (Fig. 1).

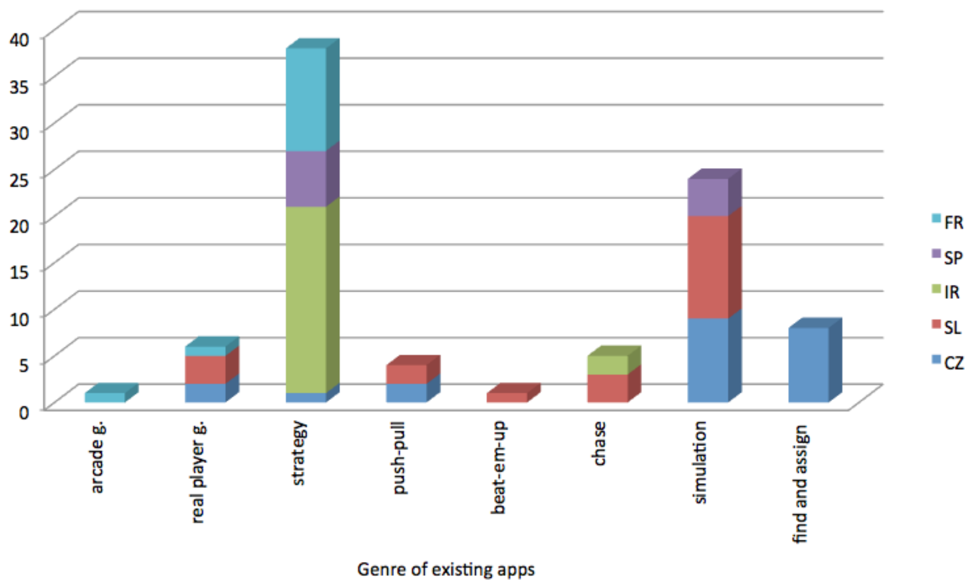

Fig. 1: Genre of existing apps, N = 87
Legend: FR – France, SP – Spain, IR – Ireland, SL – Slovenia, CZ – Czech Republic, g. – game

Instructional content

Teachers were asked to find apps that could enhance the learning of biodiversity, although many of the apps had a broader scope. Games were identified as being useful for Science and Technology courses, followed by Environmental Awareness subjects. Fewer apps were identified for general Biology and Natural

Science subjects, although some were identified as useful in Chemistry and Geography. Teachers generally did not identify apps as useful in Physics, Home economics or Technology.

The majority of the games fell within the subject Biology or Ecology although some could be used to support learning in Chemistry and Physics as well. Teachers commonly identified static digital resources, such as electronic atlases, bird sounds, etc. as useful in their practice, e.g. http://botany.cz/en/. Very often teachers selected simulation, or quizzes, for teaching biodiversity or ecosystems, for example: https://quizlet.com/, http://www.otevrena-veda.cz/nezkreslena-veda/.

Serious games focused on ecology, ecosystems, food chain, energy, nature and environmental protection. Specifically, biodiversity (21%), energy (15%) and environmental protection (14%) were the most common (Fig. 2). Differences between countries may reflect different curriculum focus, for example, France's curriculum has a strong emphasis on conservation and waste management, while Ireland focuses on developing scientific skills such as observations and classification.

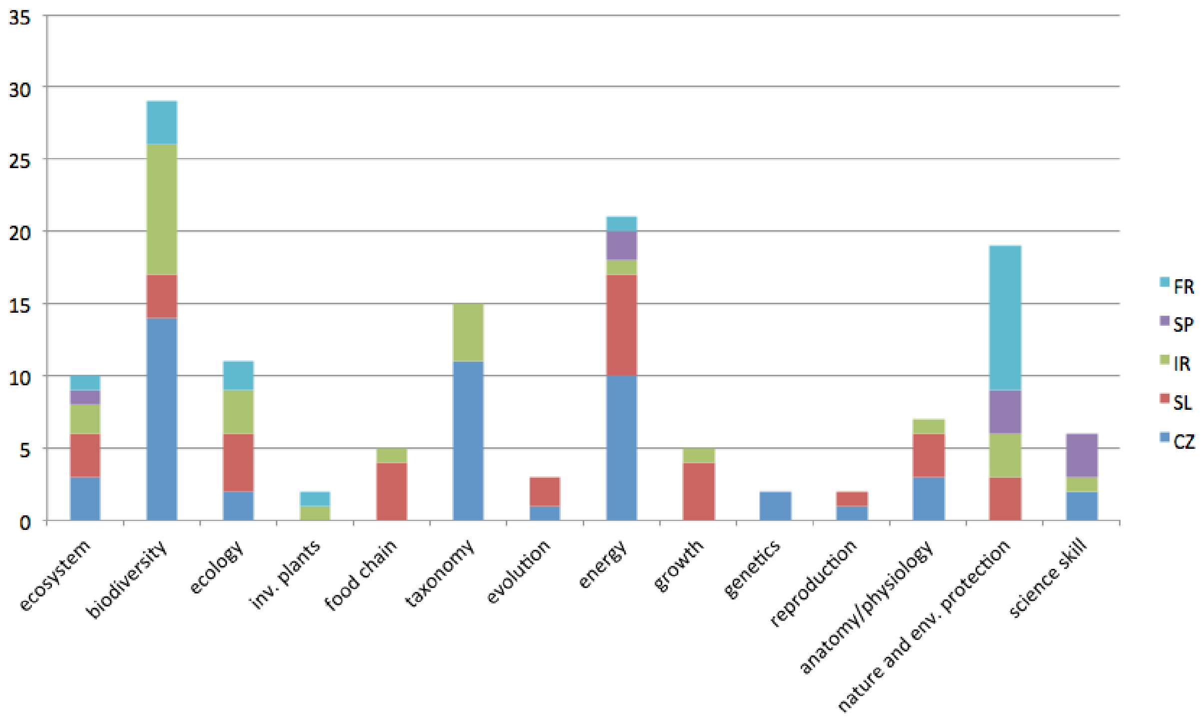

Fig. 2: Content addressed in the game N= 137
Legend: FR – France, SP – Spain, IR – Ireland, SL – Slovenia, CZ – Czech Republic

Which learning objectives from the curriculum could be achieved?

Teachers were asked to identify key learning objectives that could be achieved through playing or using the apps they had reviewed. These learning outcomes aligned with the instructional content of the app. The major divisions included: biodiversity, ecology, taxonomy, structure and function of organisms, evolution and human impact on the environment. In addition, scientific skills, such as observing, discussing and predicting were identified as objectives that could be reinforced or learned in some of the apps. Table 4 outlines some learning objectives identified by teachers under various categories. In general, more plant or food-web focused apps were identified by teachers from all countries, however, some differences were identified; the French team focused more on sustainability and waste recycling than biodiversity and the Slovenian and Czech Republic teams selected more taxonomic apps.

Table 4: *Some learning objectives identified in games and apps available online*

Form and Function	Ecosystems, Ecology, Evolution	Human Impact, Sustainability	Scientific Skills
Understand principles of photosynthesis and cell respiration: know products and the reactants of photosynthesis and respiration and how both processes are connected	Understand ecosystems, food chains and relations between species Understand the interdependence of a wide variety of living things and their environments	3 pillars of the sustainable development: social, environmental and economic challenges	Develop the skills of observation and reflection in and on action
Know names of different parts of plants	Know that plants are producers and animals are consumers of organic mater	Develop an appreciation of carbon emissions and how they contribute to environmental damage	Develop a knowledge and an understanding of scientific ideas through the study of living things and the environments in which they live
Know that for growth, plants needs water light and soil	Know how to construct simple food chains and combine them into food webs	Understand how to maximise wind / solar energy captured to power homes/ businesses	Actively discuss, explore and work toward resolutions of environmental issues
Know basic structure of flower	Explain the importance of environmental equilibrium and ecosystem balance	Identify recyclable material	
Recognise sounds in nature	Learn about different weather phenomena	Learn to sort waste Learn to build compost	
Know the metamorphosis and life cycles of some animals	Learn about properties of air Learn about air pollutants		
Learn the names of: plants, insects, birds, fish in the local environment and acquire some knowledge about them.	Know water cycle Understand water protection		
	Explore environmental repercussions of human actions on natural environments		
	Recognise the importance of conserving habitats and environments Understand that life depends on the sustainable development of the planet		
	Understands that evolution is basic property of living things	Explore and appreciate the influence that scientific and technological developments have had on societies, lifestyles, economic activities and the environment	
	Understand the geographical influence on evolutionary adaptation		
Predict the impact of human's action in the natural environment and evaluate these actions			

Which type of knowledge is mainly acquired by playing the game?

Various types of knowledge and capabilities can be gained through using apps. The majority of apps (43%) were identified as providing pupils with the opportunity to acquire conceptual knowledge. This knowledge is associated with linking ideas and concepts together and is acquired in apps and games that allow pupils to build complex interactions with solid content knowledge, such as in biodiversity and food web design. 37% of apps identified by teachers had a declarative knowledge component. Declarative knowledge ("know that...") forms the instructional content of the curriculum in the classroom (Pash et al., 1998) and can be developed primarily through static and interactive digital resources, (show the various organism, events, videos, images, animations, etc.). Each curriculum has its own structure and that is made up of facts from which the classification of the creation of concepts occurs (Bruner, 1956). Finding relationships between concepts leads to a generalization and the ability to create declarative knowledge depends also on procedural knowledge (Odom, Kelly, 2001). Procedural knowledge ("knowing how…") allows students to perform specific activities and develop certain practices. Simulation games are a good example of a game that focuses on procedural knowledge and 20% of the apps teachers sourced from the internet fell into this category.

Language

The majority of apps identified were English only (55.8%) although all countries found some apps in their native language. The teachers generally preferred digital resources in their native languages, but they also used resources in English. In most countries, it is not a problem for children, approximately 10–14 years, to play the game in English and this could allow for a language component to the lesson.

Recommended age of the children

Teachers recommended existing apps more for younger than older children. Most (41%) of the existing apps were identified as suitable from 9 to 11 years old children, the next age group was 15 to18 years old children (20.5 % of apps), then 6 to 8 years old children (17.7 % of existing apps) and finally 12 to 14 years old children (15.8 %). Only less than 1 % found the apps and games suitable for students over 18 years of age.

First corresponding target groups are teacher, because before lecture is necessary try the apps. Second suitable target groups are pupils and students.

Hardware

When schools are purchasing equipment to support e-learning they need to determine which hardware best supports the software they intend to use. Our teachers found the majority of the games and apps (57 %) were designed to be played with Windows software, while 4% were designed for an android. 10 % of the identified apps could be played with either Windows or an android. Apps were generally not designed for IOS Apple systems, although 21% could be used with windows, IOS or android system (Fig. 3).

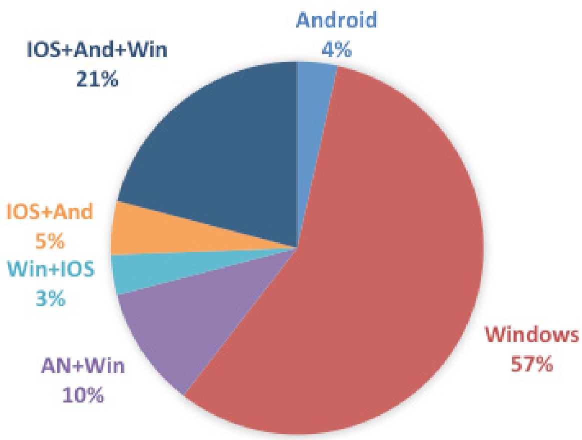

Fig. 3: Hardware requirements for apps. N = 86

Conclusion

This paper has presented the evaluation of existing apps which teachers in schools could use during their teaching practice. There were a wide variety of games and apps selected and evaluated by teachers. The majority of the apps fell within the biology/ecology subject area and, since the teachers were instructed to identify apps useful for biodiversity, it is not surprising that the electronic resources related largely to biodiversity or taxonomy. Differences in selection of apps between countries are likely a result of their respective curriculum foci, however all teachers found relevant apps that could be used to meet specific learning outcomes. Teachers identified the static digital resources as most useful in their general practice, while they chose simulations and quizzes for reinforcing ecosystem and biodiversity subjects. This suggests that the discovery-based elements of digital resources (as found in serious games) are still underutilized and teachers tend to use digital sourced material for didactic, declarative learning or assessment.

Serious games are educational resources which can motivate pupils to learn and help transfer skills. Serious games have a place in teaching and learning but teachers need to purposefully identify the learning objectives and allow a discovery-based approach to learning in their classroom. Most of the games identified were supported by computers and this could be problematic. In many countries, there is a push toward purchasing tablets for students and this may limit teachers' use of games and reinforce the use of static digital resources geared for personal tablets.

This evaluation of existing apps allowed teachers to identify digital resources that could enhance their lessons and engage students in a variety of learning opportunities. Teachers now have a collection of games they could access that could meet specific learning objectives. Most teachers found some apps in their native language however the majority were English only. In addition, some games did not contain regionally specific biodiversity or taxonomy. This affords the opportunity to develop and customize serious games to meet country-specific requirements.

Serious games can be an effective tool for teaching and learning if executed with purpose and intention. A wide variety of apps are available on the internet and using them can have a positive impact on engaging students in learning if teachers reflect on their application to specifically meet curriculum learning objectives.

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Appendix A : All existing apps

Name of the app	URL / link to find the app	Instructional Content	This App works on this Hardware	Game genre	Intended learning outcomes (key words)	Language	Target audience
Le tour du monde en 80 déchets	http://www.sytrad.fr/pedagogique/college2.htm	Environment, geography, sciences and civic education	Android, Windows	arcade game	To sort waste.	french	7 - 12
Les maîtres de l'eau	http://eau.paris/game/	Environment	Windows	real player game	The cycle of water.	french	
Simagro	http://www.ac-nice.fr/svt/productions/html5/simagro/index.htm	Science, biology	IOS, Android, Windows	strategy	Sustainable development, the economic, environmental and social factors, evolution of a natural environment, agriculture.	french	10+
EcosysGame	http://ecosysgame.fr/index.html	Ecosystems, biodiversity	IOS, Android, Windows	strategy	Sustainable development: social, environmental and economic challenges, name of animal and plant species, the food chain, biodiversity.	french	10+
L'éco-missaire mène l'enquête	http://www.developpement-durable.gouv.fr/spip.php?page=ile_ecomissaire	Environment, biodiversity	Android, Windows	strategy	Energy wastage, biodiversity, environment.	french	7 - 11
L'eau dans tous ses états	http://jeux.education.francetv.fr/eau_etats/	Environment	Windows	strategy	Water.	french	9 - 13
Ma petite planète chérie	http://mapetiteplanetecherie.crdp-lyon.fr/enfantsjeux.php	Biodiversity	Windows	strategy	Water treatment systems, the food chain, environment, vegetation.	french	6 - 8
L'eau c'est la vie	http://www.kailis-design.net/haya/	Energy and matter cycles	Windows	strategy	We learn that water is an important resource that must be saved.	french	10 - 12
Le bon trieur	http://www.valorplast.com/jeux/jeu2.swf	Environment	Android, Windows	strategy	How to classify wastes.	french	10 - 12
Alterosion	http://www.alterosion.fr	Environment	IOS, Windows	strategy	The selective sorting, the composting, the re-use, the management of dangerous waste, the cunning and responsible purchase.	french	10 - 14
ROUGER	http://www.valorplast.com/tous-recycleurs/valorplast/actionnaires/	Environment	IOS, Windows	strategy	Children learn to sort plastic packaging based on their content.	french	10 - 14
Trions bien rangeons tout	http://www.sytrad.fr/pedagogique/default2.htm	Environment	Windows	strategy	Recyclable and non-recyclable item. Then be able to choose the right bin.	french	10 - 14
Ma maison, ma planète et moi	http://www.cite-sciences.fr/au-programme/evenements/ma-maison-ma-planete/	Environment	Windows	strategy	Water of each point in the house (washing machine, shower ...) how to reduce by choosing drinking water or water unsuitable drinking.	french	8 - 11
Flow	http://www.jenovachen.com/flowinggames/flowing.htm	Biodiversity, ecosystem	IOS, Windows	strategy	Predation, reproduction (artificial organism), evolution.	english	6+

Name of the app	URL / link to find the app	Instructional Content	This App works on this Hardware	Game genre	Intended learning outcomes (key words)	Language	Target audience
Nature vs Beasts	Google Playstore	Nature	IOS, Android	strategy	Observation and reflection in and on action. Adjusting your approach to achieve a desired outcome.	english	10 - 12
Biodiversity Game	http://ngm.nationalgeographic.com/2011/01/seven-billion/biodiversity-game	Biodiversity	IOS, Android, Windows	strategy	You can learn just how many species there are of different life forms. The figures themselves are quite staggering and of interest.	english	8 - 12
Bio Bob's Diversity Adventure	http://www.rigb.org/education/games/natural-world/bio-bob	Biodiversity	IOS, Android, Windows	strategy	Understand what some species do in order to survive in two different enviroments; Arktica and Tropikania.	english	6 - 8
Build a Skeleton	http://www.rigb.org/education/games/human-body/build-a-skeleton	Science, biology	IOS, Android, Windows	strategy	Learn about the variety of bones that make up different creatures in various habitats across the world.	english	6 - 11
Pond Life	http://www.rigb.org/education/games/natural-world/pond-life	Ecosystem	IOS, Android, Windows	strategy	Understand how different species depend on other species for different reasons.	english	7 - 12
Team WILD	http://www.arkive.org/education/team-wild	Biodiversity, ecology, ecosystem	Windows	strategy	Conservation of endangered plants / animal species.	english	6 -13
Sammy's Quiz	https://itunes.apple.com/ai/app/sammys-quiz/id1008159202?mt=8	Nature and environmental protection	IOS, Android	strategy	Recognise plants and animals in the environment. Factors of pollution and ways to combat pollution.	english	7 - 12
Offset!	http://climatekids.nasa.gov/offset/	Environment, energy	Windows	strategy	An appreciation of carbon emissions and how they contribute to environmental damage.	english	8 - 10
Power Up	http://climatekids.nasa.gov/power-up/	Environment, energy	Windows	strategy	How to maximise wind / solar energy captured to use to power homes/ businesses.	english	8+
Go Green	http://climatekids.nasa.gov/go-green/	Environment	Windows	strategy	How to cause least damage to the environment using the most energy-efficient form of transport.	english	7+
Plant Snap	App Store/Google Play	Biodiversity, taxonomy	IOS, Android, Windows	strategy	Learn the names of plants in the local environment and acquire some knowledge about them.	english	6+
Eco Tour	https://play.google.com/store/apps/details?id=com.BitEnslaved.EcoTour&hl=en	Biodiversity, environment, biology	IOS, Android	strategy	Become familiar with some of the flora and fauna of the Sanok region.	english	7 - 11
Eco	https://www.strangeloopgames.com/eco-account/home	Environment	computer / android	strategy	Environmental problems.	english	10 - 11
Invaders	http://pbskids.org/plumlanding/games/invaders/	Environment, invasive species	IOS, Android, Windows	strategy	Native species of many countries around the world. The pupils will also learn about the negative impact of invasive species on areas.	english	8, 9,10

Name of the app	URL / link to find the app	Instructional Content	This App works on this Hardware	Game genre	Intended learning outcomes (key words)	Language	Target audience
Park Builders	http://pbskids.org/naturecat/game.html?park-builder	Environment, ecosystem, taxonomy	IOS, Android, Windows	strategy	Plants and animals, park. Environment.	english	7, 8, 9
Seed Soaring	http://pbskids.org/naturecat/game.html?seed-soaring	Biology, taxonomy, reproduction	IOS, Android, Windows	strategy	How plants germinate. Conditions needed for plants to grow.	english	5, 6
Feed the Dingo	http://pbskids.org/plumlanding/games/ecosystem/feed_the_dingo.html	Ecosystem, food chains and webs	IOS, Android, Windows	strategy	Plants and animals in an ecosystem for it to function correctly.	english	8 - 12
Scratch	www.scratch.mit.edu	App	IOS, Android, Windows	strategy	Coding	english	7+
skeptical	https://skepticalscience.com/skeptical-science-iphone-app.html	Biodiversity, taxonomy	android	strategy	by provinding some challenges	english	15-18
ecogator	http://www.ecogator.es/	Ecology	android	strategy	By providing various challenges	spanish	12+
Pollution	https://itunes.apple.com/app/pollution/id304218687?mt=8	Ecology	android	simulation	pollution informs you about your local pollution sources, and their measured exposures	english	12+
tryp fuel calculator	https://itunes.apple.com/es/app/trip-fuel-calculator/id389034937?mt=8	Ecology	Android, Windows	simulation	Quickly calculate your trip cost, based on how far you travel. Taking into account saving energy	english	18+
Europeair	https://www.eea.europa.eu/mobile/apps#europeair	Ecology	Android, Windows	strategy	EuropeAir app.	english	14+
Marine LitterWatch	https://www.eea.europa.eu/mobile/apps#marine-litter-watch	Ecology	Android, Windows	strategy	European master list of commonly found marine litter items, such as cigarette butts, bottles, fishing materials…	english	15-18
Ihuerting	https://itunes.apple.com/es/app/ihuerting/id464683669?mt=8	Biodiversity, taxonomy	Android, Windows	simulation	This app help us to take care or our garden	spanish	12+
Guia de reptiles en España	https://itunes.apple.com/es/app/guia-de-reptiles-de-espana/id507875329?mt=8	Biodiversity, taxonomy	Android, Windows	strategy	This app provide a complet guide of spanish reptiles	spanish	12+
Ornita - Sounds of birds	http://www.ornita.cz/online-hra/	Biodiversity, taxonomy, anatomy and physiology	IOS, Android, Windows	find and assign	-know some of common bird species	czech	12 - 18
Biological library	http://www.biolib.cz/	Biodiversity, taxonomy	Windows	find and assign	biological library	czech, english	12 - 18
Botanical fotogallery	http://www.botanickafotogalerie.cz/	Biodiversity, taxonomy	IOS, Android, Windows	find and assign	biological library	czech, english	12 - 18
Botanical photogalery	http://botany.cz/en/	Biodiversity, taxonomy	Windows	find and assign	Czech or english version of botany web (mainly aimed to herbarium, mushrooms and flora)	czech, english	12 - 18

Name of the app	URL / link to find the app	Instructional Content	This App works on this Hardware	Game genre	Intended learning outcomes (key words)	Language	Target audience
Czech web about insects	http://www.hmyz.net/	Biodiversity, taxonomy	Windows	find and assign	Czech web about insects	czech	12 - 18
Květena ČR	http://www.kvetenacr.cz/	Biodiversity, taxonomy	Windows	find and assign	Czech web about flowers in Czech republic.	czech	12 - 14
Ecotoxicology	www.piskac.cz/ETD/Default.htm	Ecotoxicology	Windows	find	Czech web about Toxicology, Medication	czech	15 - 18
Hot Potatoes	https://hotpot.uvic.ca/	Reproduction, genetics	Windows	find	English web with sex applications, enabling you to create interactive multiple-choice, short-answer, jumbled-sentence, srossword, etc.	english	15 - 18
Encyclopaedia Britannica	www.britannica.com	Biodiversity	Windows	simulation	Encyclopaedia with quizzes, galleries, spotlight	english	15 - 18
Muzeum nás baví	http://www.muzeumnasbavi.cz/	Biodiversity	Windows	real player game	Czech simulation games about ecosystems and biodiversity	czech	12+
Nezkreslená věda	http://www.otevrena-veda.cz/nezkreslena-veda/	Biology/Chemistry/....	IOS, Android, Windows	simulation	Web and popular videos. For example evolution, periodic table, computers, AIDS, imunity ...	czech	8 - 18
Simulation of Atom	https://phet.colorado.edu/sims/html/build-an-atom/latest/build-an-atom_en.html	Science	IOS, Android, Windows	Simulation	Simulation of Atom	english	10 - 18
Hlas pro tento den	http://www.rozhlas.cz/hlas/portal/	Biodiversity, taxonomy	IOS, Android, Windows	simulation	Web about birds and other animals (pictures, sounds, informations ...)	czech	8 - 18
Operace kolene	http://zemepis-a-prirodopis-online.webnode.cz/news/operace-kolena/	Anatomy and physiology	Windows	simulation	Surgery simulation of knee.	english	8 - 18
4D anatomy	http://anatomy4d.daqri.com/	Anatomy and physiology	Windows	real player game	4D models of heart and human body	english	8 - 18
Hlasy zvířat	http://forest-nature.iplace.cz/menu/zvuky-zvirat	Biodiversity, taxonomy	Windows	simulation	Biodiversity, taxonomy	czech	8 - 18
Ekopolis	http://www.ekopolis.cz/	Ekosystems	Windows	simulation	Simulation game about metropolitan ecosystem, protection of nature	czech	12 - 14
Gravity/Match	https://quizlet.com/	Other (definition and concepts)	Windows	push-pull	Create sets to assign concepsts and definition or pictures and names	english, czech and many others	6+
Vítejte na Zemi - hry	http://vitejtenazemi.cenia.cz/hry/	Ekosystems, biodiversity, ecology, taxonomy	Windows	simulation, push-pull	A few games about rivers, trees, revitalization, circulation, geosystem etc.	czech	10 - 18
Smart chytej	http://www.smartchytej.cz/	Biodiversity, taxonomy	IOS, Android	strategy	Czech web and app. about fish and fishing	czech	15 - 18
Atlas hub	https://play.google.com/store/apps/details?id=cz.ihoubar.atlashubfree&hl=cs	Biodiversity, taxonomy	IOS, Android, Windows	simulation	Czech application about mushrooms	czech	10 - 18

Name of the app	URL / link to find the app	Instructional Content	This App works on this Hardware	Game genre	Intended learning outcomes (key words)	Language	Target audience
Extinct - plant survival game	http://www.bbsrc.ac.uk/bbsrc/cache/file/277CD3E7-6173-4352-931C3364FA5CED83.swf	Ekosystems, biodiversity, ecology, photosynthesis	Windows	simulation	Photosythesis, sexual reproduction of plants, anatomy and growth of plants, crops.	english	12 - 14
Growing plants	http://www.bbc.co.uk/schools/scienceclips/ages/5_6/growing_plants_fs.shtml	Ekosystems	Windows	chase, simulation	Plant morphology, light, water.	english	6 - 8
Sheppard Software - Preh.verige	http://www.sheppardsoftware.com/content/animals/kidscorner/games/foodchaingame.htm	Food chains and webs,energy and matter cycles	Windows	push-pull	Learning about ecosystems, food chains and relations between speces.	english	9 - 11
Določevalni ključi-ptiči	http://www2.pms-lj.si/kljuci/vrtne-ptice/	Biodiversity,ecology, food chains and webs	Windows	simulation	Learning about biodiversity, food chain, natural ecosystems.	slovene	9 - 11
Vedeževo e- gradivo za spoznavanje okolja	http://vedez.dzs.si/dokumenti/dokument.asp?id=1491	Phenomena: sound, light, weather	Windows	real player game	Shadows, sources of lights and reflection, weather phenomena, sounds.	slovene	6 - 8
egradiva	http://egradiva.e-cho.org/home/	Nature and environmental protection	Windows	real player game	Waste separation.	slovene	9 - 11
bbc	http://www.bbc.co.uk/schools/scienceclips/ages/5_6/growing_plants.shtml	Growth, development and differentiation	Windows	chase, simulation	Students know that for growth plants needs water, light and soil.	slovene	9 - 11
Vreme in pojavi	http://vedez.dzs.si/dokumenti/dokument.asp?id=1491	Phenomena: sound and light	Windows	real player game, chase	Different weather phenomena, sounds in nature, shadow.	slovene	6 - 8
Snovi in gibanje - ZRAK - 3.razred	http://vedez.dzs.si/dokumenti/dokument.asp?id=1491	Matter, materials	Windows	chase	Air and air pollutants.	slovene	6 - 8
Bioman	http://biomanbio.com/GamesandLabs/EcoGames/ecology.html	Ecosystems, biodiversity, ecology, energy and matter cycles, nature and environmental protection	Windows	push-pull	Water protection, food webs, balance in ecosystems, predict the impact of humans actions in natural environments and evaluate these actions.	english	9 - 14
Bbc	http://www.bbc.co.uk/schools/scienceclips/ages/9_10/life_cycles.shtml	Evolution	Windows	chase	Production of plants food, water is circulating between living organisms and environment.	english	9 - 11
Bbc	http://www.bbc.co.uk/schools/scienceclips/ages/10_11/interdependence.shtml	Food chains and webs	Windows	simulation	Plants are producers and animals consumers of organic mater, construct simple food chains and combine them in food web, environmental equilibrium.	english	9 - 11
Bioman	http://www.biomanbio.com/GamesandLabs/PhotoRespgames/phorespgame.html	Energy and matter cycles	Windows	strategy game	Plants food and oxygen is produced from water and carbon dioxide, energy is coming from the sun, chlorophyl is catalyst in this process.	english	12 - 14

Name of the app	URL / link to find the app	Instructional Content	This App works on this Hardware	Game genre	Intended learning outcomes (key words)	Language	Target audience
Life cycles	http://www.bbc.co.uk/schools/scienceclips/ages/9_10/life_cycles.shtml	Anathomy and phsiology	Windows	chase	Basic structures of flower.	english	12 - 14
Prehranjevalna veriga (Food chain)	http://www.sheppardsoftware.com/content/animals/kidscorner/games/foodchaingame.htm	Food chains and webs	Windows	simulation	Different parts of food chain.	english	9 - 11
Razvojni krog? (Life cycles)	http://www.sheppardsoftware.com/scienceforkids/life_cycle/butterfly_lifecycle.htm	Reproduction	Windows	simulation	Metamorphosis and life cycles of some animals.	english	12 - 14
Bioman ekologija (Bioman ecology)	http://biomanbio.com/GamesandLabs/EcoGames/ecology.html	Ecology	Windows	beat-em-up	Water circle.	english	9 - 11
Fotosinteza in dihanje (Photosynthesis and breathing)	http://www.biomanbio.com/GamesandLabs/PhotoRespgames/phorespgame.html	Energy and matter cycles	Windows	push-pull	Photosynthesis and cell's breathing.	english	9 - 11
Darwinovi ščinkavci (Darwin's birds)	https://www.livescience.com/32409-whats-so-special-about-darwins-finches.html	Evolution	Windows	simulation	Evolution is basic property of living, role of geographical location for evolution.	english	12 - 14
Fotosinteza (Photosynthesis)	http://www.biomanbio.com/GamesandLabs/PhotoRespgames/photointeractive.html	Energy and matter cycles	Windows	simulation	Photosynthesis (what is needed).	english	12 - 14
Živalska celica (Animal cels)	http://www.biomanbio.com/GamesandLabs/Cellgames/CellExplorerAnimalCell.html	Anatomy and physiology	Windows	simulation	Parts of cell.	english	12 - 14
Fotosinteza (Photosynthesis)	http://www.biomanbio.com/GamesandLabs/PhotoRespgames/phorespgame.html	Energy and matter cycles	Windows	simulation	Products and the reactants of photosynthesis and breathing and how both processes are connected.	english	12 - 14
Agregatna stanja / Sate of matter	http://www.bbc.co.uk/schools/scienceclips/ages/9_10/gases.shtml	Matter- materials	Windows	simulation	Structure and dispersion of particles in different states of matter.	english	12 - 14
Sound and hearing	http://www.bbc.co.uk/schools/scienceclips/ages/5_6/sound_hearing.shtml	Sound	Windows	simulation	Sources of sound, sound is produced when object are moving (vibrates).	english	12 - 14
Mikroorganizmi	http://www.bbc.co.uk/schools/scienceclips/ages/10_11/micro_organisms_fs.shtml	Anatomy and physiology	Windows	simulation	Role of microorganisms in ecosystems (decomposers...).	english	12 - 14

5 TEACHERS' DIGITAL COMPETENCE DEVELOPMENT THROUGH APPS AND DIGITALS STORIES ABOUT DIODIVERSITY

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Abstract
Primary and secondary school teachers, who teach natural sciences involved in the TEALEAF project developed not only knowledge about biodiversity and ecology but also they developed their digital competence. Through the project selected teachers from Czech Republic, France, Ireland, Slovenia and Spain in the first phase used applications and digital data sources and in the second phase developed their own apps: games, simulations and digital stories. In this paper, in the theoretical part we describe the meaning of digital competence in the context of education. In the empirical part we analyze teachers' safe-reflective questionnaire responses about their knowledge, skills and attitudes, developed through the project activities.

Keywords: Digital competence, apps, TEALEAF project, teaching ecology and biodiversity

Introduction

The 21st century, known as the "digital era" by some (e.g., Shepherd, 2004), bringing new challenges to modern society. As is widely recognised nowadays, digital technologies are key drivers of innovation, and in particular they changed the world in the last two decades of the last century. The availability of information-communication technology (ICT) per se, in Europe at least, is not considered a problem anymore: almost 100% of the population owns a mobile phone and 81% of families have Internet access at home. As with any tool, wider reach however is not a sign of ability to use these technologies. In 2015, 67% of the EU population aged between 16 and 74 was using the Internet every day. However, a study shows that almost half of this population had either "low" or "no" digital skills (Kluzer & Rissola, 2015).

In 2006 the digital competence was recognised by the European Parliament and the European Council as one of eight key competencies essential for all individuals in a knowledge-based society, which is also important for lifelong learning (Digital Single Market, 2014).

The European Digital Competence Framework for Citizens, also known as "DigComp", offers a tool to improve citizens' digital competence. DigComp was developed by the Joint Research Centre (JRC) of the European Commission as a scientific project. It was first published in 2013 and has become a reference for the development and strategic planning of digital competence initiatives at both European and Member State levels. DigComp 2.0, presents Phase 1 of the update, which focuses on the conceptual reference model. The report also shows examples of its implementation at the European, national and regional levels (Vuorikari, Punie, Carretero Gomez, & Van den Brande, 2016). DigComp is the European framework, which gives common understanding of the digital competence that citizens need to participate in today's society: knowing how to look for, assess and use information; how to communicate

through various channels; how to produce and share digital content; how to use digital technology safely and critically in everyday life, including work (Kluzer & Rissola, 2015).

The teaching professions face rapidly changing demands (REF). The frequent use of digital devices and applications requires educators to develop their digital competence. As changes of education are focused on students' digital competence, in our research we are concerned with equipping teachers with digital skills. The objective of DigCompEdu is to identify and describe the key components of educators' digital competence. The DigCompEdu framework is directed towards educators at all levels of education, from early childhood to higher and adult education, including vocational training, special needs education, and non-formal learning contexts (Redecker and Punie, 2017).

In our research we are concerned with the digital competence teachers need to have in order to improve the teaching practices related to specific topics, such as ecology and biodiversity. We are talking at the same time about dealing with digital devices and compiling digital learning resources, and about technical skills, which are joined with pedagogical competence. We are focused on development of digital competence among primary school teachers involved in the Teaching Ecology Through Apps: Learning Engagement And Fun – TEALEAF project with aim of instructional planning for their own education and implementation of teaching practices in schools for developing understanding of ecology topics among students.

This paper is in three parts. In the first part, we describe the meaning of DigComp and its areas, outlining the framework, and providing some examples of its implementations. In the second part we outline the project activities with teachers, realizing the development their digital competence needed for teaching biodiversity and ecology topics. In the third part we outline the empirical research in which teachers from the project countries reflect their opinion about their knowledge, skills and attitudes before/after the project activities.

Digital competence

Competence is personal characteristic (e.g. skills, knowledge, attitudes) that an individual possesses or needs to acquire, in order to perform an activity within a specific context, whereas performance may range from the basic level of proficiency to the highest levels of excellence (Poldoja et al, 2014).

Digital competence is related to many 21st Century skills which should be aquired by all citizens, in order to ensure their active participation in society (Ala-Mutka, 2011) and it enables acquring other competencies (Ferrari et al., 2014). Digital literacy consists of the ability to access digital media and ICT, to understand and critically evaluate different aspects of digital media and media contents and to communicate effectively in a variety of contexts (Fig. 1). Digital competence is more then liteacy, it involves the confident and critical use of ICT for employment, learning, self-development and participation in society. Digital competence development is based on: 1) Instrumental knowledge and skills for tool and media usage; 2) Advanced skills and knowledge for communication and collaboration, information management, learning and problem-solving, and meaningful participation; 3) Attitudes to strategic skills usage in intercultural, critical, creative, responsible and autonomous ways. The proposed structure allows flexibility and the concept to be tailored to different target groups of digital competence learners and users. Developing digital competence should be considered as a continuum from basic skills towards advanced knowledge, skills and attitudes (Ala-Mutka, 2011).

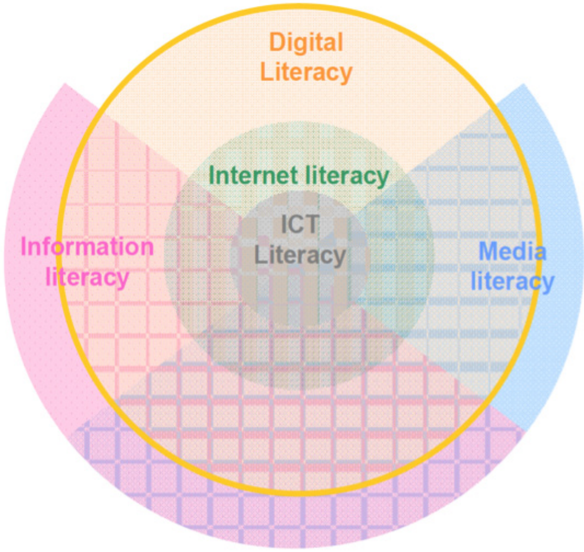


Fig. 1. Digital literacy and other literacies (Source: Ala-Mutka, 2011)

From 2013 till now (2017), DigComp has been used for multiple contexts: employment, education and training, and lifelong learning. The fast moving digitalization of various aspects of society sets new requirements; hence the need for DigComp version 2.0 (Vuorikari et al., 2016) is obvious. Regarding to the framework 2.0, the DigComp conceptual reference model identifies 5 broad areas of digital competence broken down into 21 competencies (Table 1). For each of the listed competence areas, were identified a series of corelated competencies.

Table 1. *The DigComp 2.0 framework areas and competence (Kluzer & Rissola, 2015)*

1 Information and data processing	**2 Communication**	**3 Content creatlon**	**4 Safety**	**5 Problem solving**
Identify, locate, retrive, store, organise and analyse digital information, judging its re evance and purpose	Communicate in digital environments, share resources through online tools, link with others and colloborate through digital tools, interact with and participate in comunities and networks, cros-cultural awarness	Create and edit new content (from word processing to images and video); integrate and re-elaborate previous knowledge and content: produce creative expressions, media outputs and programming; deal with and apply intellectual property rights and lincences	Personal protection, data protection, digital identy proptection, security measures, safe and sustainable use	Identity digital needs and resources, make informed decisions on most appropiate digital tools according to the purpose or need, solve conceptual problems through digital means, creatively use technologies, solve technical problems, udate own and other's competence
1.1 Browsing, searching and filtering information 1.2 Evaluating information and data 1.3 Storing and retreiving information and data	2.1 Interacting through digital technologies 2.2 Sharing information and content through digital technologies 2.3 Engaging in citizenship through digital technologies	3.1 Developing content 3.2 Integrating and re-elaborating 3.3 Copyright and licences 3.4 Programming	4.1 Protecting devices 4.2 Protecting personal data and privacy 4.3 Protecting heakt and well-being 4.4 Protecting the environment	5.1 Solving technical problems 5.2 Identifying needs and technological responses 5.3 Creatively using digital technologies 5.4 Identifying digital competence gaps

Framework, conceptual model, implementations and assessment

One of the important aims of the DigComp is planning education and training initiatives to improve digital competence of specific target groups. DigComp also provides a common language on how to identify and describe the key areas of digital competence and thus offers a common reference at European level (Ferrari et al., 2014), (Nančovska Šerbec et al., 2017). Several organizations in European Union are already using DigComp in different ways at the local and national level and there are also various European wide implementations. JRC-IPTS regularly updates a Gallery of Implementations of DigComp in Europe, classified in four areas, as in the Fig. 1.). For purposes of our research we are interested in the fields of teacher professional development and E&T content/student assessment. For example, in Slovenia, the National Education Institute translated the documents and analyzed the primary and secondary school curriculum regarding to the digital competence development. In this research we used DigComp framework for student digital skills and knowledge assessment, which could be used on different levels of education (Juvan, 2016), (Nančovska Šerbec et al., 2017).

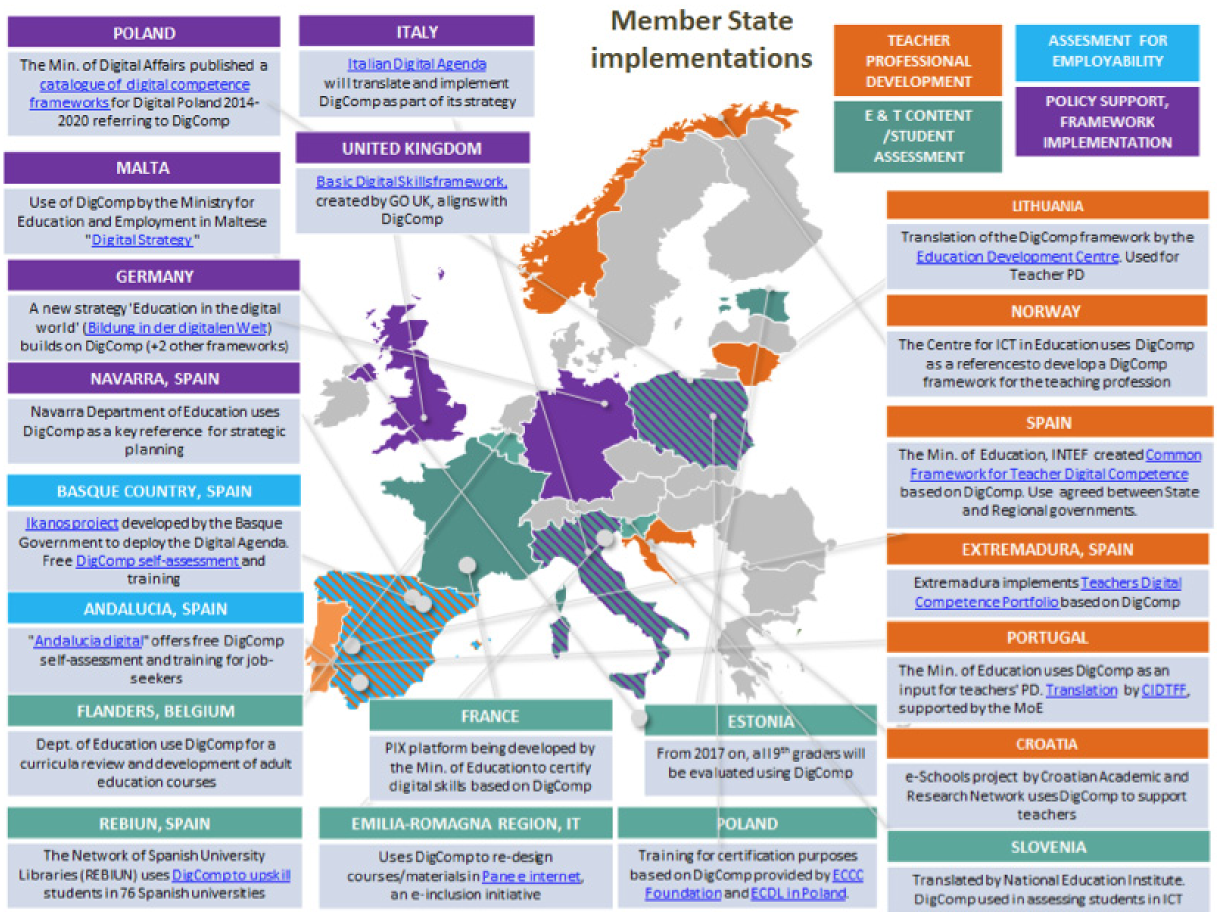


Fig. 2. A snapshot of Member State implementations (Source: https://ec.europa.eu/jrc/en/digcomp/implementation, in December 2016)

Many projects funded by European Union were carried out about the development of DigComp among the EU citizens. We are interested in teacher education, which influences the level of mastery of their students. The results of extensive research in Norway on 125 schools showed that when school leaders reported higher levels of culture for professional development among the teachers at school, increased levels of digital competence were found among students (Hatlevik et al., 2015). Measuring and assessing individuals digital competence is a complex process. There are many aspects and areas of knowledge and skills of digital competence. In different conuntries different types of measurement tools are used to determine the level of achievement of digital competence of individuals.

Ala-Mutka (2011) described three main measurement types of individuals' digital competence: user questionnaires (often self-assessments), analysis of digital tasks (skill-tests) and secondary data gathering and analysis. Self-assessment tools are frequently used for making individuals to develop an understanding of digital competence, of its components (skills, knowledge, attitudes) and of the DigComp framework's structure and for analyzing the current and desired levels of each particular area, which is case in our paper. Therefore, beyond other more direct aims, self-assessment tools should be seen also as a component of DigComp's broader communication strategy (Kluzer & Rossola, 2015), as it was in our research.

There are a variety of projects and frameworks dealing with digital competence of teachers, some of them are developed in EU (such as DigCompEdu), others in USA, Asia, Australia or internationally (such as UNESCO's and ISTE's frameworks). Well-known project is Mentoring Technology Enhances Pedagogy (MENTEP), still (2017) running in EU. All this frameworks and projects aim at a single goal: teacher professional development, with goal directed, creative in meaningful use of technology.

DigCompEdu

The purpose of DigCompEdu is to identify and describe the key components of educators' digital competence. It is framework model based on the analysis, mapping and clustering of the elements constituent of educators' digital competence, as these are detailed in existing national and international frameworks, self-assessment tools and certification schemes (Redecker and Punie, 2017).

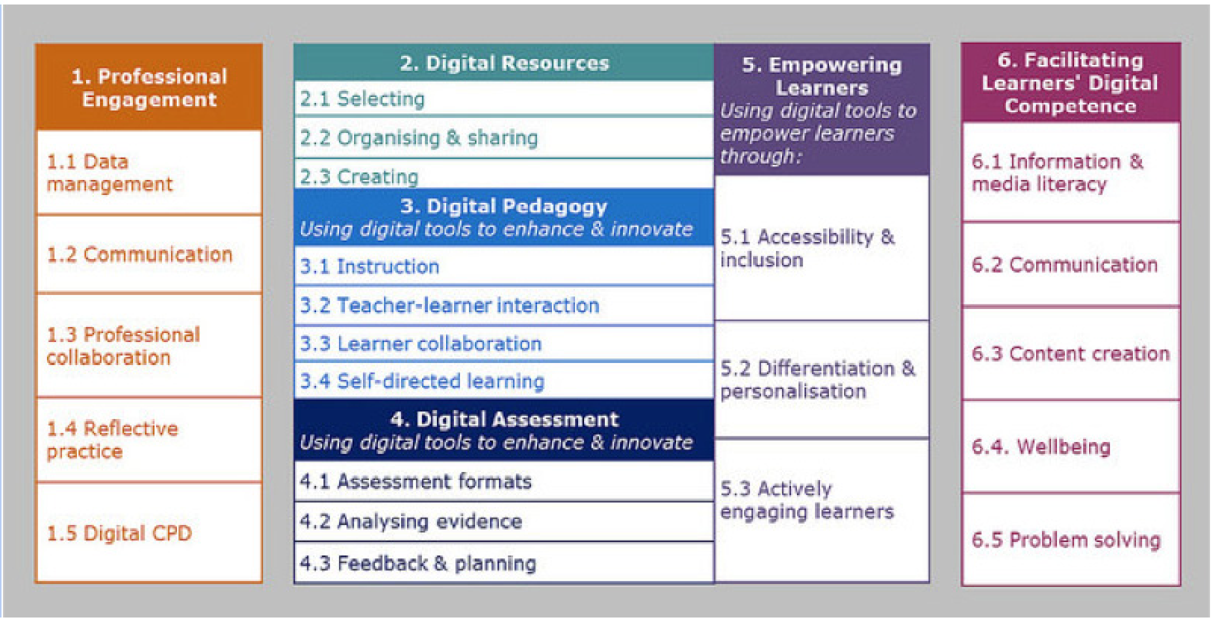


Fig. 3. Overview of the DigCompEdu framework (Source: DigCompEdu Leaflet, 2017)

In collaboration with the European Commission's DG Education and Culture, the Joint Research Centre (JRC) of the European Commission has developed a proposal for a framework to define and measure educators' digital competence, the DigCompEdu framework. This framework, once refined and validated, will help policy makers, education institutions and educators themselves to better understand existing levels of digital competence and to plan for targeted training. DigCompEdu considers six areas of professional activity and describes how digital competence is expressed in each of them. Area 1 focuses on the professional environment; Area 2 on sourcing, creating and sharing digital resources; Area 3 on managing and orchestrating the use of digital tools in teaching and learning; Area 4 on digital tools and strategies to enhance assessment; Area 5 on the use of digital tools to empower learners; Area 6 on facilitating learners› digital competence. Areas 2 to 5 form the pedagogic core of the framework (Rekecker and Punie, 2017).

In this research we are concerned with areas 2, 3 and partially 4 and 5.

Through the project teachers developed digital, subject-specific and pedagogical competencies (Fig. 4). Regarding to studies on Norwegian teachers (Krumsvik, 2014, 2016), teachers' digital competence can be considered the teachers' skill to use them. The use of these technological resources by teachers implies much more than merely technically mastering them, but the pedagogical use of sources and applications It is also necessary to consider that teachers use them in their educational practice. Therefore, competence relates to the degree (how much) and purpose (how) they use technology to enhance the educational process. In turn, the model of teachers' digital competence is based on four dimensions: basic digital skills (handling ICT), didactic digital competence (using ICT in the subject matters taught), learning strategies (using ICT in the education context) and digital bildung (ethical and moral reflections on ICT use) (Røkenes and Krumsvik, 2016).

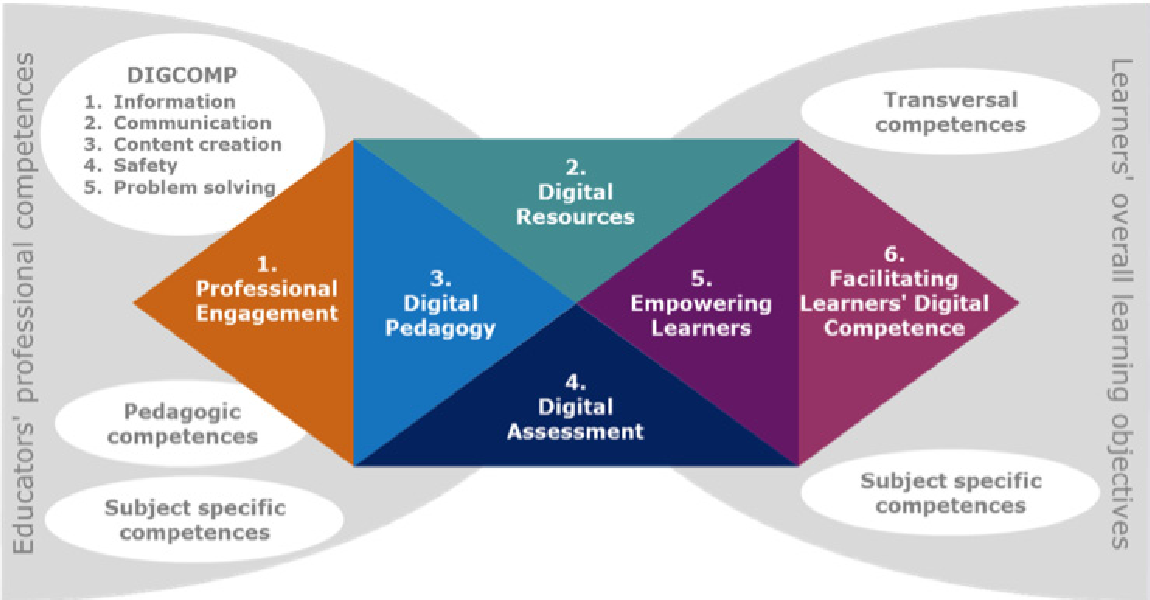


Fig. 4. DigCompEdu: from educators' competence to learners' objectives (Source: DigCompEdu, 2017)

TEALEAF activities for digital competence development and examples of digital resources

Through the project, teachers from Czech Republic, France, Ireland, Slovenia and Spain who participated the project, used and developed digital resources and applications related to topics of ecology and biodiversity.

In the first phase they researched the existing digital resources and apps related to the selected topics and adopted them to their own teaching practice. Teachers together with the project academic stuff developed learning and assessment materials.

A good example was the use of simulation-game "Extinct" (http://www.bbsrc.ac.uk/engagement/schools/keystage4/extinct/). Teachers used the game in the classrooms, and students' knowledge after the playing was assessed, by means of other digital resources (mind maps, tests). With these activities, teachers developed competence of areas of digital resources and digital pedagogy

In the second phase, teachers develop their own digital resources, apps and simulations. In July 2016 there was organized teachers' workshop in Dublin, Ireland. Teachers in multinational group develop their own games, apps, simulation and other digital resources. The project work can be described in following steps with key points in italics:

1. First teachers were given a lesson on biological foundations of *biodiversity*.
2. They were also given *technological support*, such as introduction to visual programming environment Scratch and game creation platform Stencyl.
3. Teachers formed international *groups* with 4-5 members and started with project work.
4. Each group started with creation of its own story or game on biodiversity or ecology. First members selected topics, collected digital materials, write scenario and prepare a *storyboard* about their game/story.
5. They published their materials on selected *blog*. After the workshop groups finished their work by means of collaborative work.
6. After the workshop teacher continued with project *collaborative work* in order to finish the game/story. Some groups took help in programing by university students, studying computer science.
7. After the finishing story developed pedagogical strategies to use the prepared games and materials in the classroom and to orchestrate the learners.

All the digital products developed through the project are published on the project website (TEALEAF, 2015).

Through all this steps teachers built their own digital competence in all its areas: Information area was supported by steps 4; communication by step 6, digital content creation by steps 4 and 5, safety by 5 and problem solving by solving problem of game installation at schools. At the same time, regarding to DigCompEdu, teachers developed also their professional competence through step s 1. and 2 and developed digital pedagogy competence through 7.

Research

The purpose of our research, performed after the project activities, was to analyze the opinion of teachers who participated TELEAF project towards their previous and current level of mastery of teachers' digital competence. We wanted to find out the areas in witch teachers by their opinion got the most by project activities, to analyze the possible weaknesses of the activities in the project and to find out what the needs of teachers were about their professional development and digital competence mastery.

Instrument

For self-assessment of teachers' knowledge, skills and attitudes, we used questionnaire prepared in "Google Forms'" which allowed us to create, execute and analyze online surveys. Questionnaire consists of demographic data and a self-assessment grid, designed according to research literature on expectations on project outputs.

Questions were devided into three domains: knowledge, skills and attitudes. For each question teachers were asked to assess their previous and current level. They were asked to select their previous/current level of knowledge, skills, attitudes on a scale from 1 – strongly disagy to 5 – strongly agree..

Sample

In our research 38 teachers form 5 countries participated (Fig. 5). About 60% of the participants were female (Fig. 6).

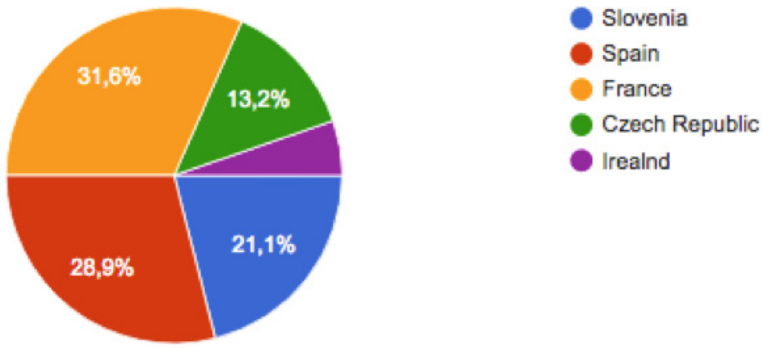


Fig. 5. Percentage shares of teacher regarding to country of residence.

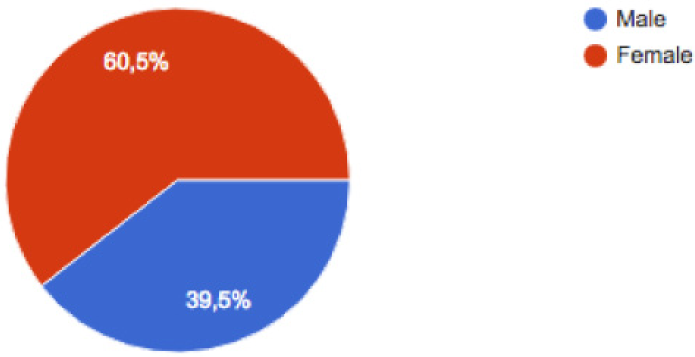


Fig. 6. Percentage shares of teachers regarding to gender

Results

The aim of our research is to analyze the teachers' self-perceived previous and current levels of specific knowledge, skills or attitudes.

Knowledge

Table 2. *Number and procentage of well self-assesst teachers before and after the project for each question (Knowledge)*

Teachers' knowledge			
Question	# of teachers and % good assessed before project	# of teachers and % good assessed after project	Difference in %
I know well, why program Scratch is used for.	9 23%	32 84%	61%
I know well, why program Stencyl is used for.	4 10%	26 68%	58%
I know also other programs (apart from Scratch & Stencil) for preparing e-learning materials.	7 18%	25 66%	47%
I know how to prepare a simple animation in Scratch.	8 21%	27 71%	50%
I know how to use serious (applied) games or apps for teaching.	11 29%	34 89%	60%
I know how to implement serious (applied) games or apps for motivation of learners.	10 29%	29 76%	52%

I know how to implement the same serious (applied) game or apps for different learning goals or outcomes.	5 13%	26 68%	55%
I know how to implement serious (applied) games or apps into lesson plan.	10 26%	32 84%	60%
I have a good overview of serious (applied) games or apps available for biodiversity and ecology education.	6 16%	32 84%	68%
I am competent in evaluating the quality & usefulness of particular serious (applied) games or apps for biodiversity and ecology education.	6 16%	25 66%	50%
I know what the term biodiversity means.	21 55%	33 87%	32%
I understand why is important to teach about biodiversity and ecology.	24 63%	34 89%	26%
I know how to implement biodiversity themes into teaching.	15 39%	31 82%	42%
Average %	**27%**	**78%**	**51%**

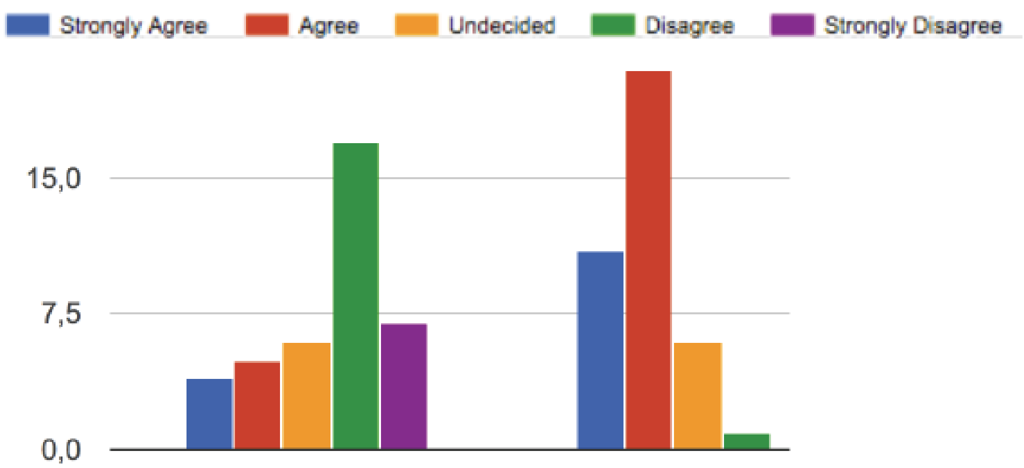


Fig. 7. Knowledge question 1: I know well, why program Scratch is used for. Self-assessment: previous (left side) current knowledge (right side).

In Table 1 we can see the percentages of teachers who assessed their knowledge well ("strongly agree" and "agree") before and after the project. The biggest change (68% in average) in the knowledge before and after the project was about question 9 (good overview of serious (applied) games or apps available for biodiversity and ecology education). The average change of knowledge captured by questions before and after the TEALEAF is more then 50%.

From Fig. 7 we can see the participants' percentage growth related to Scratch knowledge before and after the project. Only one participant after the project is undecided. From Fig. 8 we can see that more 70% respondents think that they can prepare animations in Scratch after the project ("agree" or "strongly agree"). Before the project 70% of the participants assessed their knowledge on making animations with "disagree" or "strongly disagree".

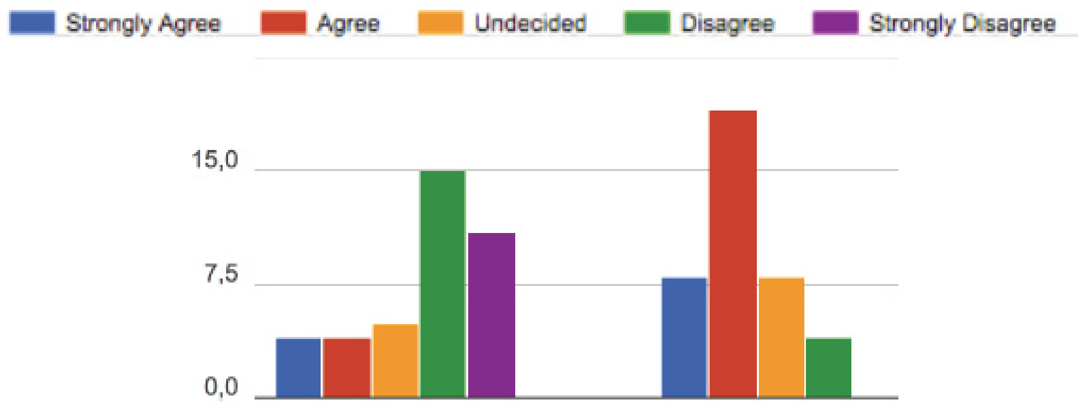


Fig. 8. Knowledge question 4: I know how to prepare a simple animation in Scratch. Distribution of self--assessments through 5 categories (on the top) : previous (left side) current knowledge (right side)

Skills

Table 3. *Number and percentage of well self-assesst teachers before the project and after it for each question (Skills)*

Teachers' skills			
Question	**# of teachers and % good assessed before project**	**# of teachers and % good assessed after project**	**Difference in %**
I know how to find serious (educational) games or apps on the web	10 26%	31 82%	56%
I know how to publish information on the web page.	10 26%	24 63%	37%
I can download, upload and install games without major difficulties	14 37%	26 68%	32%
I understand quickly how serious (educational) games or apps work.	11 29%	34 89%	61%
I have no major problems in giving students instructions on how to use computers and serious (educational) games or apps in the class	15 39%	29 86%	37%
Average %	**32%**	**76%**	**44%**

From the Table 3 we can see that after the TEALEAF project the majority of teachers feel that they improved their understanding of the mechanisms of apps and games, which is important project output. The average change of skills captured by questions before and after the TEALEAF is 44%.

Attitudes

From the Table 4 we can see that after the TEALEAF project the majority of teachers (76%) support the use of serious (educational) games or apps in teaching, which is an important project output. It is interesting that the project did not affect the general attitude towards the use of ICT in the classroom. The average change of attitudes captured by questions before and after the TEALEAF is 22%.

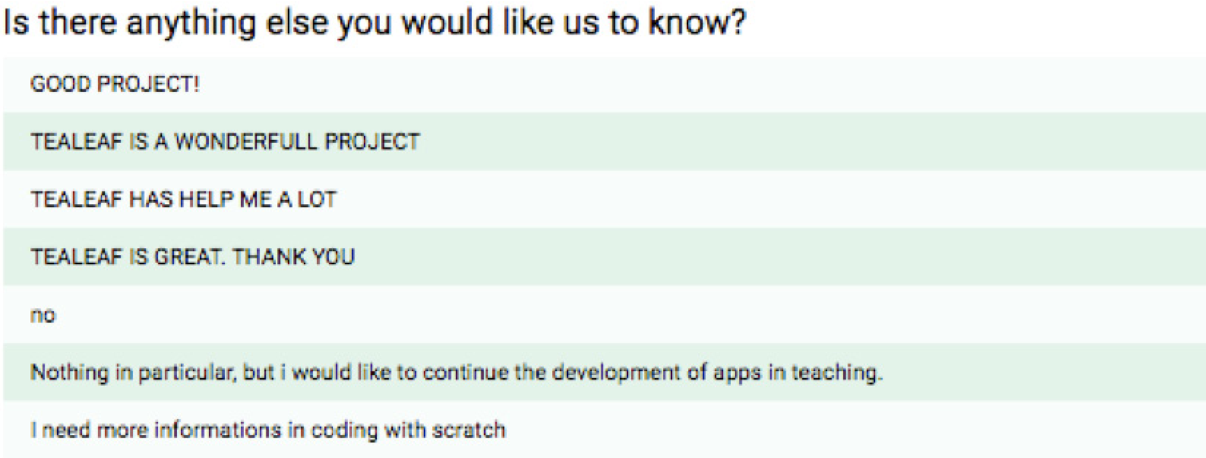
Table 4. *Number and procentage of well self-assesst teachers before the and after the project for each question (Attitudes)*

Teachers' attitudes			
Question	**# of teachers and % good assessed before the project**	**# of teachers and % good assessed after the project**	**Difference in %**
I prefer to use ICT in my lessons	29 76%	29 76%	0%
I support the use of serious (educational) games or apps in teaching.	15 39%	29 76%	37%
I support my coworkers in school to use serious (educational) games or apps in teaching.	12 32%	25 66%	34%
There should be more ICT-assisted teaching in schools.	21 55%	30 69%	24%
ICT helps students to experience things more actively and lively.	22 58%	32 84%	26%
ICT can help students to reason better.	15 39%	23 61%	21%
Immediate and dynamic feedback makes student lazy in their thinking	8 21%	16 42%	21%
As a teacher, you can't see what is learnt through the ICT.	10 26%	16 42%	16%
Average %	**40%**	**62%**	**22%**

Teachers' reflections on TEALEAF project

In the Fig. 9 and Fig. 10 are given teachers' reflections on the TEALEAF project. We can see that teachers had positive experiences with the TEALEAF project regarding the use of apps and games in their teaching.

Fig. 9. TEALEAF benefits, teachers' oppinion.


Is there anything else you would like us to know?

GOOD PROJECT!

TEALEAF IS A WONDERFULL PROJECT

TEALEAF HAS HELP ME A LOT

TEALEAF IS GREAT. THANK YOU

no

Nothing in particular, but i would like to continue the development of apps in teaching.

I need more informations in coding with scratch

Fig. 10. TEALEAF teachers' reflections.

Conclusions

In this paper we outlined the importance digital competence in education. We stress the teachers' digital competence and we describe the frameworks proposed in the EU for its modeling. We outlined how we supported the development of digital competence of teachers with TEALEAF project activities.

In the research we analyzed the self-reflective assessments of previous/present levels of achievement of knowledge, skills and attitudes of teachers involved in the TEALEAF project, who completed the questionnaire. The biggest difference between previous and the current is in the field of understanding of apps and serious games about biodiversity and ecology (Table 2). Teachers also appear to better understand the mechanisms of apps and games for these topics. The majority of the teachers felt that they knew how to prepare their own simple animation in visual programing environment, Scratch and how to use it in the classroom.

Regarding to DigComp 2.0 framework (Fig. 3), teachers individually developed competence from all five fields of digital competence. Regarding the DigCompEdu framework (Fig. 4), teachers developed not only digital competence, but also pedagogic, subject specific and even transversal competence.

From the Fig. 9 and Fig. 10 we can see that teachers expressed positive experience with the TEALEAF project about use of apps and games in their pedagogical practice, which is important project result.

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6 “We had plenty of ideas and it was very interesting to exchange” – TEALEAF TEACHERS AS A COMMUNITY OF PRACTICE

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Introduction

The TEALEAF project bridges academic research and classroom practice. Participants are primary and secondary school teachers whose classrooms and schools are sites for intentional investigation of the role of serious games in teaching and learning about biodiversity.

In July 2016, forty-eight teachers from the five countries represented in the TEALEAF project – France, Ireland, Slovenia, Spain and the Czech Republic- came together in Dublin for a one-week intensive summer school. The aim of the summer school was to enable teachers participating in the project to come together to share their ideas and experiences around biodiversity and serious games, develop their ICT skills, and use this understanding to create new computer-based games that could be used in their classrooms.

The summer school was deliberately designed to reflect a constructivist approach to learning – building on previous ideas, exploring, working in groups, reflection, dialogue and discussion – with an emphasis on hands-on, collaborative learning. Following some initial plenary lectures, teachers worked together in smaller groups to construct their games.

The aim of this Chapter is to explore in detail the teachers’ experience during and after the summer school, to look at the benefits and challenges of such a collaborative approach and to explore the relationship between learning and community in the context of the TEALEAF project.

Theoretical framework and background

Teacher learning can be understood to consist of three distinct types, ‘knowledge-for-practice’, ‘knowledge-in-practice’, and ‘knowledge-of-practice’ (Cochran-Smith & Lytle, 1999). Knowledge *for* practice is the formal knowledge and theory teachers use to improve practice (as may be found in an academic environment, undergraduate or postgraduate programmes of education). Knowledge *in* practice can be thought of as that practical knowledge that teachers acquire borne of experience in the classroom, embedded in practice and in reflection on practice. Knowledge *of* practice, then, is “the knowledge teachers need to teach well”, and is generated when “teachers treat their own classrooms and schools as sites for intentional investigation at the same time that they treat the knowledge and theory produced by others as generative material for interrogation and interpretation” (ibid.). Thus, teachers learn by working together in inquiry communities to generate local and collaborative knowledge of practice; theorising and deconstructing their own work and connecting it with a wider context. This is the foundation upon which the TEALEAF project is constructed. Teachers from five European countries undertake research in practice in their classrooms and come together to exchange ideas and share their experience.

Modern learning theories emphasise the social context in which learning occurs. In 1991, Lave and Wenger proposed a theoretical framework of learning as a social process that is situated within communities of practice

(Lave & Wenger, 1991). They defined these as "groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly." This collaboration over time enables the practitioners to share ideas and strategies, determine solutions, and build innovations. (Wenger, 2000)

Shared features of a community of practice

According to Wenger (2011), there are three characteristics crucial to communities of practice – domain, community and practice. Thus, a community of practice has an identity that is defined by a shared *domain of interest*. A shared commitment to and competence in the domain of interest distinguishes members of the community of practice from other people. Members value their collective competence and learn from each other. Teachers recruited to the TEALEAF project share a common interest in using technology for teaching and learning about biodiversity. Some are specialists in computers and information technology (ICT), some are biologists, but they all share a desire to inquire more deeply into the possibilities afforded by serious games.

It is a *community*, where members interact and learn together, help each other and share information. With TEALEAF, this interaction is supported through regular meetings and online via a web platform.

Finally, members of a community of practice are *practitioners*, who develop a shared repertoire of experiences, stories and tools. Development of this shared practice takes time and sustained interaction. TEALEAF practitioners are all educators, who have come to know each other over the course of the project.

These three elements – domain, community and practice – together constitute a community of practice; and as Wenger (2011) states "it is by developing these three elements in parallel that one cultivates such a community".

In Lave and Wenger's original model, communities of practice occur naturally in place of work or among professional colleagues. However, in the years since this framework was initially described, there has been much discussion of the role of communities of practice in education, where such communities describe a process of knowledge generation, application and reproduction that occurs within an authentic context, through identity with and shared participation in communal practice. Thus, while communities of practice cannot be 'made to order', they can be supported and fostered by educators and instructional designers (Hoadley, 2012). In TEALEAF, project co-ordinators have brought together a knowledge-building community of teachers and education professionals to work together towards a specific learning goal. Hoadley and Kilner (2005) argue that such a knowledge-building community, if sustained, can constitute a specific community of practice, one where the core practice is an inquiry one. However, the question now is whether we have managed to develop a TEALEAF community of practice, and if so, whether this can continue to have a life and a value beyond the scope of the original inquiry.

Methods

The findings of this qualitative study are derived from analysis of a number of data sources.

Daily Reflections

During the week of the summer school in Dublin, at the end of each day participants were asked to complete a short self-evaluation via a number of reflective questions (Appendix 1). The purpose of this self-evaluation tool was to satisfy Irish Department of Education and Skills (DES) requirements for accreditation for the summer school, however the responses to the reflective questions also provide useful insight into the teachers' thoughts and experiences through the week.

Online Exit Survey

Shortly after their return home from the Dublin summer school teachers were asked to respond to an online survey via Google Forms. The survey questions can be seen in Appendix 2. A total of 36 responses were received, a 75% response rate, with a country breakdown as illustrated in Fig 1.

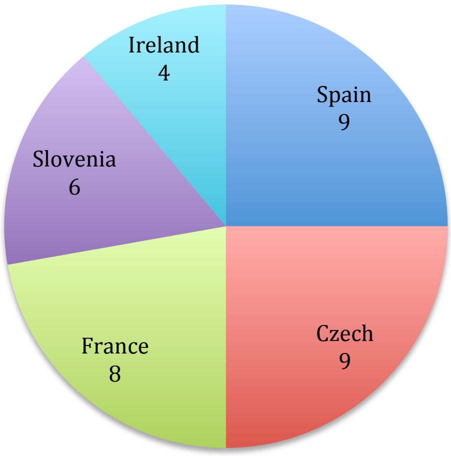

Figure 1. Online survey responses by country. The number of responses from each country is indicated in each segment

In-person Interviews

Analysis of the survey responses identified several recurring themes. To follow up in more detail on these, several teachers were also interviewed in person on a one-to-one basis. Initial questioning was based on an interview schedule (Appendix 3) designed around the themes that had emerged from the online survey. Six teachers were interviewed, with each interview lasting approximately 30 minutes. Interviews were held either in the interviewee's home institution or during the Laval symposium (Table 1).

Table 1. *Teachers interviewed for the study*

Teacher Name*	Country	Background	Game team	Interview date/ location
Yan	Slovenia	Primary teacher	Bark Beetle	26/5/17, Ljubljana
Mila	Slovenia	Primary teacher (11-14 year olds); biology, home economics, general science	Busy Bees	26/5/17, Ljubljana
Larry	Czech Republic	Secondary teacher; biology, chemistry and information technology	Food Web Chain/Create Your Own Forest	5/7/17, Laval
Paul	France	Secondary teacher; technology	Hayon's Odyssey	5/7/17, Laval
Yves	France	Primary teacher; headmaster	Worm Your Way Out	5/7/17, Laval
Nuala	Ireland	Primary teacher; learning support	Busy Bees	5/7/17, Laval

* Participant names are pseudonyms chosen by the researcher to protect identity.

Data Analysis

Using a qualitative approach, the constant comparative method was employed for data analysis. In general, data analysis followed seven broad phases; organising the data, immersion in the data, generating categories and themes, coding the data, offering interpretations through analytic memos, searching for alternative understandings and finally, writing this report (Marshall & Rossman, 2010). Dominant and recurrent themes were identified and combined to constitute categories of meaning and then re-evaluated. Findings are presented in line with conceptual themes from literature review and data collection instruments.

Results: Teacher views and experiences

The summer school ran for one week, Monday – Friday, for 5 hours per day. There were plenary lectures for the first day and a half, and after that the teachers worked in groups to design and build biodiversity-related computer games, using Scratch or Stencyl. Each group consisted of between and eight participants, drawn from each of the different participating countries. Thus, over the course of the week, there were five 2.5 hour group work sessions, and a final presentation session where each group presented their work to the collected participants. In total there were 48 participant teachers on the course.

Initial impressions

The daily reflections show that the teachers were preoccupied with the details of creating an interesting and useful game, struggling with the challenge of working and conversing in English, and getting to grips with software such as Scratch and Stencyl. However, the impact of working and learning in community can also be discerned

> I have more ideas about biodiversity learning because of the group's ideas.
>
> I would be happy to throw in any old picture [into the game], but my teammates' attention to using the best quality images and paying attention to fine detail made me realise that sometimes it's important to take more care. Maybe I had been rushing to get something finished, even though it wasn't my best work.
>
> I have seen how and what other people are doing in their groups. I can use this after the games are done.

These three teachers are acknowledging the positive effect that working together in with others is having on their learning. They can see a use for and benefit to their collaboration beyond the immediate task of creating a game.

Indeed, as will be seen later, when the teachers reflect back on the summer school afterwards, working collaboratively in groups is one of the aspects of the course that they most enjoyed.

Working in groups was not without its challenges, however, as expressed by many of the teachers in these initial reflections. For example, halfway through the week one teacher commented that she struggled "to reach an agreement with people who have different educational experiences and different viewpoints". Another teacher highlighted that "it's already difficult to work together when you understand each other, and it's more difficult when you don't understand."

However, within their groups the teachers discovered ways of working together to surmount the difficulties, such as using Google Translate, or assigning a leadership role to one of the group, generally someone who was fluent in English.

Towards the end of the week, teachers were already beginning to reflect on their experience of working collaboratively and to look towards the future.

It's a really rich experience to share with another European teacher. I'd like to make it again in the future.

I will use my colleagues' knowledge, i.e. those with a specialty, to understand a subject/topic better.

Both of these teachers recognised the value of connection with their international colleagues for their own learning and practice. For all of the teachers, the group learning approach taken during the summer school, whether challenging or enjoyable, gave them something that they could bring to their classroom. As one teacher said "I like challenges like this, because it makes my teaching better".

Looking back

These initial impressions are reinforced in the teachers' reflections post-Dublin. From the responses to the online survey we can build a picture of the teachers' experience, and the elements that were of most importance to them.

What the teachers identified as most enjoyable about the summer school was the opportunity to meet and work with other teachers, and in particular with teachers from other countries (Figure 2a). This gave them the opportunity to share their experiences of teaching and classroom practice, and to make international links for future collaboration,

I met many teachers from other countries. We have exchanged and shared many advices [sic], opinions and experiences from our education systems. I hope I will keep in touch with some teachers. (Questionnaire 13)

The opportunity to work together collaboratively in small groups was also important to them, and afforded opportunities to exchange ideas and learn from each other's skills and expertise, "pooling resources and getting to know other people's strengths" (Questionnaire 32). They also appreciated the informal and collaborative learning environment.

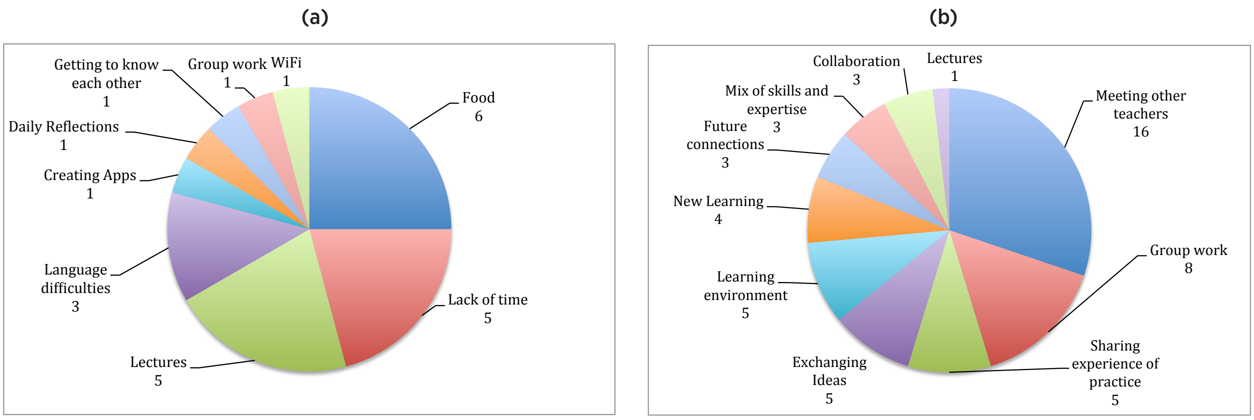

Figure 2. Categorised responses to online survey, (a) what teachers enjoyed most, (b) what teachers enjoyed least about the summer school (frequency of response indicated for each category)

When asked to describe what they least enjoyed about the summer school, practical issues such as food and limited WiFi access featured strongly (Figure 2b). Teachers also felt that they were under considerable time pressure to come up with a serious game of sufficient quality to be interesting and relevant in the classroom; "maybe there was not enough time to finish our game properly" (Questionnaire 11). Language difficulties created a barrier to collaboration and understanding, and contributed to the lack of enjoyment of the lecture component of the course.

The teachers greatly enjoyed working together in groups, and identified a broad range of benefits that this approach afforded, including "the relationships with colleagues" (Questionnaire 27) and "working with people with a mix of skills" (Questionnaire 2). Sharing of knowledge and practice, working collaboratively, learning new concepts and skills, and the opportunity to discuss and collaborate with other teachers all rank highly among the teachers' responses (Figure 3a). Teachers also appreciated the opportunity to improve their language skills, however challenging that might be.

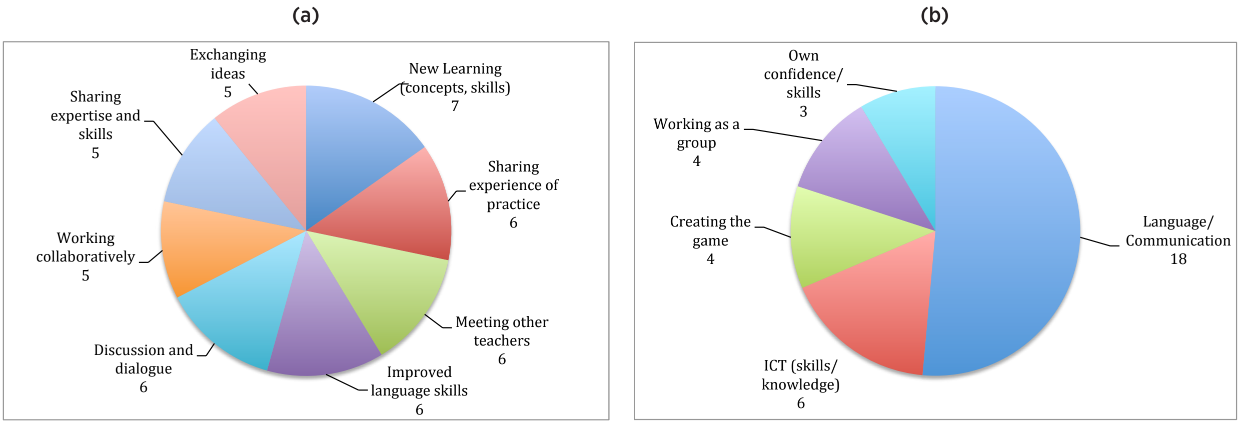

Figure 3. Categorised responses to online survey, (a) what teachers found most useful, (b) what teachers found most challenging about working in groups (frequency of response indicated for each category)

Perhaps unsurprisingly, language difficulties proved to be the most commonly identified challenge among the teachers (Figure 3b). For many, this proved to be the only challenging aspect of group work, although some teachers struggled with issues of confidence; for example, one teacher struggled with being "prepared to offer my own ideas" (Questionnaire 20).

Overall, the teachers expressed how much they benefited from the course, and many commented on their hopes and intentions for the future

> I was really happy to be here. I was full of energy after the summer course. I would like to make exchange program for my students with some other country. (Questionnaire 13)

> It is very useful to meet with teachers from other countries and share and exchange experiences face to face; it is encouraging for further work in education. (Questionnaire 14)

These comments encapsulate the feelings – the positivity, energy and collaborative spirit - expressed by all of the teachers who responded to the survey.

Looking deeper

The themes identified in the exit survey were echoed and expanded on by teachers in interviews. Each of the teachers interviewed commented on what they valued most about their experience of the TEALEAF project, and the Dublin summer school in particular.

Connections

It is interesting that for all of the teachers the key element is the connection they have made with other teachers. Larry identified straight away that the most important thing for him was meeting teachers from other countries. Nuala's initial expectations were that the focus would be mainly on the games produced during the project, but she now feels that it has been more about connecting with teachers from other countries. As she said,

> While the game and the end product is important, what I feel will be more long-lasting is the connection that we've made, and the new ideas, and realising that we're not alone in our classrooms.

This sentiment was echoed by each of the other teachers interviewed. For Yves, biodiversity offered a support, a subject with which to begin discussion, but the focus of the summer school was communication with other teachers, "about how we teach, how we progress, how we make progression for our pupils".

Working as a group

For each of the teachers, working as a group to design and build a new game about diversity was both enjoyable and useful. Collaborative, peer-to-peer learning was a hallmark of the groups. Nuala talked about other courses where sometimes teachers sat back and did not participate, and she was happy that this course was so interactive,

> you had to be involved all the time. One of the teachers from Spain taught me a lot of new things about Scratch that I wouldn't have known before, so that was great, and I was able to use it back in my own classroom.

Mila described in her interview the composition of the group she was in, and how everyone collaborated, bringing a mix of skills and experience to the group. Two of the teachers had poor English, but by using Google translate they could understand basic instructions, and were tasked with looking for suitable pictures on the internet. A teacher who was very skilled in Scratch assumed the programming role. Another teacher took on responsibility for drawing the storyboard, and between them all they discussed the form and objectives of the game. Mila saw her role as a biology specialist within her group, ensuring that the game was both accurate and meaningful from a biodiversity perspective. That everyone had a role, and that each role supported and complemented the others, was meaningful for Mila. She herself had been nervous about using Scratch, "If I don't have to work with computer I'm so glad!" so having the support and skills of another group member to take on the programming aspect was comforting.

Teachers helped each other in other ways. Larry became the "showman" for his group, because he was most comfortable presenting in English. Yves gave the group presentation for both his and another group, again because he was comfortable speaking English.

The co-operative learning strategies continued beyond the summer school. Yan's group did not get their game finished during the week in Dublin, so they enlisted the help of some computer programming students at Ljubljana University. Thus the teachers devised the concept and pedagogical aims for the game, and drew storyboards to animate their ideas, and the students completed the programming. Each group brought their particular skills and experience to the game.

Issues with communication

According to the exit survey, all of the teachers had strong intentions to stay connected and working to improve the new games following the summer school. Nuala described how in her group they had set up a mailing list while still in Dublin. However, while they used this to stay in touch regularly, they did not discuss the game in much detail during their email conversations.

Although many teachers in the exit survey said that they hoped to keep in touch via Facebook, the TEALEAF platform and Skype, in reality almost all of the groups communicated post-Dublin via email (according to teachers interviewed). This communication was patchier and more sporadic than had been envisaged. The teachers interviewed shared a general view that the biggest challenge to staying in contact after the Dublin summer school was lack of time. Once back home, work pressures and home life were a distraction from the project. According to Mila, another factor in demotivating the teachers from continuing with the work was not having a goal or deadline to work towards, "If we had a date that this must be done by, then we would steal the time somewhere, but we didn't get any instructions so we didn't make anything".

Several of the teachers made the point that if there had been a second international meeting to work towards (e.g. in summer 2017) then their groups may have been more motivated to continue to work on the games. Yan said that before the Dublin meeting, the teachers were motivated because of the upcoming summer school, but when they returned the attitude was, "Pff, it's done!" and so it became less of a priority to finish the game. Yves pointed out that if teachers knew they were going to reconvene for a second time, "the communication between teachers during the year will be more effective; you have to test and you have to communicate before seeing each other again".

However, within each country there has been more significant communication among the teachers. Coordinators have arranged regular face-to-face meetings at which the teachers have shared their progress (or lack of progress) on game completion, and shared their experiences of testing the games in the classroom. Each of the teachers commented on the usefulness of this sharing of stories, challenges and successes. For Larry, it was a motivating factor in progressing with work on his group's game, "it's good, because if everyone has made something [since last time] you must make something too".

Despite the challenges, for Yves the experience has been a positive one,

> We have progressed in English, we have progressed in programming, we have progressed in seeing teaching possibilities in other countries […]. Even if it was difficult, [at least] it happened!

Mila also has few regrets. While she feels her team could have produced a better game, "I'm not so disappointed because I got many experiences that are still important for me." These include the new games she has discovered through the project, and how talking with the other teachers introduced her to new pedagogies and approaches she could use when teaching biodiversity, "to get to pupils on a different level".

The importance of the Laval meeting

A second international meeting, this time aimed at teachers that were not previously involved with the TEALEAF project, was held in Laval, France in July 2017. While not originally intended as a reunion, some of the original TEALEAF teachers were invited to present at the symposium and/or to lead workshops introducing the new games created during the TEALEAF project. This provided an unexpectedly rich and productive opportunity for collaboration among the 'veteran' TEALEAF teachers. On the first morning they came together as a group spontaneously and began translating several of the TEALEAF games into a variety of languages. Both Yves and Larry commented on the depth and ease of communication among the teachers. This is something Nuala also highlighted, and she similarly said that it consolidated the friendships from Dublin,

> We had established common ground already from last year, so we were able to … get past the small talk and get into more important issues. We were able to have better conversations about more important things; for example, challenges in education, behaviour, pedagogical techniques. We were even discussing biodiversity and apps, where do we go from here? It seemed natural to talk about stuff like that… The social foundation has been laid and we can move on to the next level of discussion.

Looking to the future, towards sustained community

Nuala again made the point that by meeting again and continuing to work together at the Laval symposium,

> We're more motivated now to stay in touch and maybe continue on, just ourselves…Comenius projects and things like that.

She reiterated how beneficial it has been to connect with other teachers and to realise that "everyone has the same problems, the same motivations", regardless of the country or educational curriculum in which they are teaching.

The Irish teachers have also set up a WhatsApp group through which they converse regularly, exchanging classroom ideas and suggestions for teaching activities. It provides an example of the peer-to-peer learning opportunities characteristic of communities of practice, "Some of the Irish teachers are very good with technology so it's great to get some advice from them" (Nuala).

Yves and an Irish teacher on his team have maintained contact, and the children in their respective classes have become pen pals, writing to each other during the past year. Yves was disappointed that his Irish colleague could not attend the Laval meeting, as Yves would like him to visit his classroom and meet his pupils. Nuala and Mila are also in contact with each other, and Nuala plans to visit and stay with Mila in Slovenia in the near future.

As their confidence and skills increase, some of the teachers are moving towards becoming mentors in their own right. Programming skills have recently become an obligatory component of the French curriculum. Paul and Yves told how they were now working together teaching on a scheme to introduce programming skills to secondary school mathematics teachers. As they described it, "what we have done last year in Dublin in the summer course we have repeated in France afterwards"; in fact, they are using the collaborative group work approach of the summer school to generate and evaluate apps for use in assessment of mathematics learning.

Conclusions – TEALEAF teachers as a community of practice

Etienne Wenger (2000) outlined a series of design elements central to the creation of a community of practice which (intentionally or unintentionally) are mirrored in the design of the TEALEAF project. These include co-ordinated leadership, connectivity via multiple media (online and face-to-face), an active membership, and the opportunity to engage with a variety of learning projects and artefacts (Table 2).

Table 2. *The TEALEAF project mirrors the design elements of a community of practice*

Element of Community of Practice Design (Wenger, 2000)	TEALEAF project elements
Events	Regular meetings (home country); Dublin summer school; Laval symposium
Leadership	Country co-ordinators; game team leaders
Connectivity	TEALEAF web platform, Facebook page, e-mailing list
Membership	> 60 teachers/5 countries
Learning Projects (such as reviewing literature, meeting experts, connecting with research academics)	Creating and testing games and apps; presenting and hosting workshops at Laval symposium
Artifacts (documents, tools, stories etc)	Games, storyboards, game guides and evaluation documents, Teachers' Resource Guide

Thus, TEALEAF contains many of the necessary components of a community of practice. As co-ordinators, we have offered a variety of affordances for knowledge generation and sharing, including regular meetings, a web platform, specific learning projects and resource guides. These support the key elements for a sustainable community; conversation, connection, content and context (Hoadly & Kilner, 2005). But how successful has the project been in this context – has a true community formed, which has a life beyond the confines of the project, and is it sustainable into the future?

There are a number of indicators of a successful, progressive community of practice (Wenger, 2000). Firstly, the level of learning energy, or the initiative shown by members to keep learning central to their enterprise; second, the depth of mutual trust and respect, the richness of the sense of community shared by members, who should feel comfortable "addressing real problems together and speaking truthfully"; finally, the degree to which the community is aware of the repertoire (shared knowledge, experience, problems) it is developing, and the effects of this repertoire on its practice (or on each member's practice in the wider world).

A number of conclusions can be drawn from the evidence collated in this study. The energy and commitment of the teachers has been extraordinary, even in the face of considerable challenge (not least the wide geographical spread of the teachers). Several of the teachers interviewed commented on how few of their colleagues had dropped out of the project over the course of several years. Also, the initiative and willingness to contribute shown by those teachers who attended the Laval symposium, spontaneously coming together to continue to develop and improve the games they and their colleagues had been working on, indicates a profound engagement with and commitment to the project goals and to each other.

Secondly, the evidence from the exit surveys and interviews reveals the richness of the trust and community shared among the teachers. Nuala's testament to the ease and depth of conversation shared by the teachers at Laval, their 'better conversations about more important things', indicates the extent to which their relationships have grown.

The sustainability of this community outside the parameters of the TEALEAF project has yet to be determined. However, we have been given glimpses of the ways in which both of these aspects may develop over time. For one, the symposium at Laval introduced new teachers to the games, ideas and approaches developed over the course of the TEALEAF project. This symposium also gave our TEALEAF teachers a chance to move from learner to mentor roles, as they led workshops and activities with the new teachers based around the games they had created and/or used, and shared their own classroom experiences in talks and presentations with a wider audience.

Wenger (2000) asserts that the experience of participation in a community of practice continues to shape our experiences beyond a specific context. This is evidenced in many ways in TEALEAF. Yves and Paul continue to disseminate the new learning from TEALEAF, working together using the approach they had practised at the Dublin summer school to now teach programming to teachers. Several of the other teachers have mentioned how they are already collaborating with teammates from the summer school, and/or using approaches they have learned through TEALEAF. There is much evidence, from talking to teachers and analysing the exit survey, that participation in TEALEAF has had a profound effect on these teachers' classroom practice.

Although communication among teachers stalled somewhat in the year following the summer school, it is apparent that deep professional bonds were forged – for example between Yves and the Irish teacher in his group, and between Nuala and Mila. Also, there is good evidence that teacher communities within the various countries have been sustained.

Those that attended the Laval symposium were all in agreement that it provided a powerful opportunity to connect more deeply with each other, as evidenced by the spontaneous collaboration on app/game translation that occurred on the second morning. This perhaps serves to indicate how continued motivation and engagement in a community of practice could be better fostered in future projects, by including a second opportunity for participants to come together and continue their collaboration.

In conclusion, one of the outcomes of the TEALEAF project has been the development of a community of inquiry among the teachers involved with the project. Through the construction and sharing of stories about their practice, and through joint problem solving, participating teachers have come to understand more about creating and using serious games in teaching and learning, and grown and developed their teaching practice in the process. From this has grown a community of practice that we hope will be sustained beyond TEALEAF.

Coda

Nuala tells a story about visiting a French school (as part of the Laval symposium) and noticing that all of the classroom doors were open, with children moving freely between them. This, for her, encapsulates her experience of the TEALEAF project, how all of the teachers opened up and shared their experiences, their ideas and practices, and the professional challenges they face - "just open the door and talk to each other!"

Beyond the original learning goals of TEALEAF, perhaps we have also achieved something rather wonderful.

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Appendix 1. Daily Feedback Form

TEALEAF Summer Course 2016 Self-Evaluation Tool

Please answer the following questions:

1. What new knowledge did I encounter today?

2. What new skills were encouraged today?

3. What did I find difficult today, and how would I address that?

4. How will I change my practice based on what I learned today?

5. How does what I learned today change my understanding or attitude towards teaching biodiversity?

Appendix 2. Post-Dublin Survey

TEALEAF Module 3 Research Questionnaire

The objective of this survey is to gather information from participating teachers to research the impact of participation in the TEALEAF project. Thank you for taking the time to respond. The survey should take less than 10 minutes to complete, and all responses are confidential.

Question 1. To which country group do you belong?

- Czech Republic
- France
- Ireland
- Slovenia
- Spain

Question 2. How well did you know the other teachers from your country group before attending the summer school?

Question 3. What did you enjoy most about the summer school?

Question 4. What did you enjoy least about the summer school?

Question 5. With regard to working in groups:

- What was most beneficial about this?
- What was most challenging about this?
- How did you deal with this challenge?

Question 6. How will you stay connected with the other teachers in your working group?

- Facebook
- TEALEAF Platform
- Email
- Other

Question 7. How will you stay connected with the teachers from your country group?

- Facebook
- TEALEAF Platform
- Email
- Face-to-face (TEALEAF meetings)
- Face-to-face (other)
- Other

Question 8. How will you stay connected with other teachers from the course?

- I do not expect to stay connected with other teachers from the course
- Facebook
- TEALEAF Platform
- Email
- Other

Question 9. Is there anything else you would like to say?

Appendix 3. Interview Schedule

- Can you tell me some background about yourself?

  [Name, country, school type, position]

- What for you was useful about travelling to Ireland for an international summer school?
- What did you find challenging about the summer school?
- Do you think you learned anything that you might not have learned at home?
- The way that the summer school worked, with teams working together to build a game – what did you find useful about that? What was challenging? Was it what you expected?
- Who was in your working group?
- What game did your group work on?
- What do you think was your role in your working group? What role did each of the other group members have?
- How much contact did you have with the other teachers in your working group since the summer school [how many times were you in contact with each other]?
- How did you stay in contact with the teachers in your working group?

  [Email, Facebook, TEALEAF website, other]

- How much contact did you have with the other teachers in your country group since the summer school?
- How did you stay in contact?

  [Face-to-face, email, Facebook, TEALEAF website, other]

- How would you describe your experience of participating in this project?

7 USING A CONCEPT MAP TO EVALUATE PEDAGOGICAL VALUE OF A SERIOUS GAME ABOUT PLANT ECOLOGY

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Abstract
The use of serious games in engaging students while meeting curriculum learning objectives was assessed in a large-scale Erasmus Plus project. Here, we report on one component of this study; a case study where student-teachers assessed the pedagogical value of a specific game targeted to junior second-level students studying plant science. 65 student teachers in both primary and post primary education from three countries (Czech Republic, Slovenia and Ireland) were recruited, allowed to play the game and asked questions around how they would use this game in their lessons. They developed concept maps to address the question – "what school topics/concepts can students learn while playing this game?" All the participants stated they would use this game in their lessons, primarily as a recap or trigger for their lesson. From open questions and the concept maps, eight general topics were identified as elements that could be taught with this game: vascular plant parts and functions, processes in plants (photosynthesis, cell respiration), growth factors, reproduction, pollination, agriculture, and herbivores. The concept maps proved to be an effective research instrument and differences in responses relating to number of concepts, types of cross-links and misconceptions were easily identified. Overall, the pedagogical value of the game was recognized by the student teachers and they recognized multiple ways to incorporate this serious game into their lessons on plant science and ecology.

Keywords: plant ecology, botany, education, extinct, survival, serious game, concept map, Czech Republic, Ireland, Slovenia

Introduction

Plants and Serious Games in Education

Ernest Haeckel (1869) first used the word "ecology" as the science that deals with the interaction between living organisms and between organisms and their environment (Begon, Townsend and Harper 2006). Later, Krebs (1972) defined ecology as the scientific study of interactions that determine the distribution and abundance of organisms (Begon, et al., 2006). Plant ecology is a branch of ecology which studies how plants respond to their environment. In the school curriculum, this theme is usually included in biology, science and/or environmental education.

Studying and learning about plants is often considered less attractive than learning about animals and they are essentially neglected in the classroom (Reiss and Tunnicliffe, 2000). This is concerning, as plants are very important owing to their essential role in sustaining life, they have numerous ecological functions, and are also on the decline (Patrick and Tunnicliffe, 2011). Studies like Fancŏvicŏvá and Prokop (2011) revealed that students have low levels of specific plant knowledge, especially for wild plants. More specific knowledge within the area of plant science could foster increased interest in plant ecology and a clearer understanding of the critical role plants play. This begins with tapping in to the teachers' interest and understanding of the subject and finding means to engage students in learning. One method of increasing interest is through the use of serious games; however, the pedagogical value of such e-learning experiences must be identified.

The acceptance of e-learning is mostly dependent on two parameters: perceived usefulness and perceived ease of use (Chinyamurindi & Louw, 2010). Both of these aspects determine opportunities to use apps (applied or serious games) in formal and informal education. A serious game is not designed for pure entertainment and it emphasizes the added pedagogical value (Djaouti, Alvarez & Jessel, 2011). Through the combination of real-world and digital-world learning resources (Chu, Hwang, Tsai & Tseng, 2010; Kolb, 1984; Rogers, Connelly, Hazlewood & Tedesco, 2005), learning can become active, more like continuous research than a body of facts (Kubiatko & Haláková, 2009; Lee, 2013). It can successfully introduce students to scientific thinking (Ahmed & Parsons, 2013) and improve scientific literacy (Patrick & Tunnicliffe, 2011). In this way, biology courses become more attractive resulting in students significantly improving their knowledge of plants and their attitudes toward them (Fancǒvicǒvá & Prokop, 2011; Huang et al., 2010; Rogers et al., 2005).

Concept Map Theory

The relationship between concepts is an essential component of knowledge (Ruiz-Primo & Shavelson, 1996). As understanding and expertise in an area is obtained through learning and experience, the elements of that knowledge become increasingly more interconnected (Ruiz-Primo & Shavelson, 1996). The more competent a person becomes in a domain of knowledge, the more structured their understanding of the topic (Ruiz-Primo & Shavelson, 1996). With the shift from positivistic to constructivistic approaches to learning, a need to be able to ascertain the construction of knowledge in the learner required a new assessment methodology. Concept maps were developed from an understanding of constructivism as a way to demonstrate the development of complex cognitive thought in students. Concept maps are able to show and assess how new concepts and propositions are integrated into a learner's cognitive structure (Novak, 2010). They graphically represent a student's declarative knowledge within a content domain (Ruiz-Primo & Shavelson, 1996). Concept maps are "grounded on the assumption that understanding in a subject domain…is conceived as a rich set of relations among important concepts in that domain" (Ruiz-Primo & Shavelson, 1996, p.570). They probe perceived concept relatedness by having students build graphs and explicitly linked concepts (Ruiz-Primo & Shavelson, 1996).

Ausubel's hierarchical memory theory and Deese's associationist memory theory were both developed in the 1960s and were the underlying theories which led to the development of concept maps as a tool for investigating cognitive development in learning (Ruiz-Primo & Shavelson, 1996). Ausubel's hierarchical memory theory underpinned the original ideas of concept maps conceived by Novak and Gowin (1984). In this theory, learning is hierarchical with discrete, specific concepts and ideas fitting within larger, more generalized concepts and ideas (Novak, 2010). These theories informed the view of propositional knowledge defined as a semantic network. These networks are easily depicted using concept maps with directional (arrows) labelled lines. As new concepts are learned and linked into the network the networks become increasingly complex; concepts can be sub-divided and cross-links can form (Ruiz-Primo & Shavelson, 1996).

Concept maps would have a central concept at the top or in the centre of the map, and branching out from it more subordinate concepts are linked to higher concepts with labelled lines, these concepts could also be cross-linked and these represent integration between subdomains within the knowledge hierarchy (Ruiz-Primo & Shavelson, 1996). Thus, concept maps are a graphical depiction of knowledge and knowledge structure (Strautmane, 2012) and consist of nodes which represent concepts, and labelled (directional) lines which show how the concepts are interrelated (Ruiz-Primo & Shavelson, 1996; Stautmane, 2012). There are a variety of ways that they can be implemented. They can be used to determine not only what a student understands but how that knowledge is represented. There are digital resources that can be used to design concept maps (e.g. http://cmap.ihmc.us/), they can be drawn free-hand, or they can be provided to the student with empty concept nodes and/or linking phrases (Ruiz-Primo & Shavelson, 1996; Novak, 2010).

Concept maps are often used as a metacognitive tool in science education to provide students with a focused structure of the topic they are studying (Iuli & Helldén, 2004). They can also be used in assessing student learning (Reiska & Soika, 2015) and identifying mis- or alternative conceptions (Van Zele, et al., 2004). Concept maps can also be an effective tool for research when determining differences in understanding between different groups, and can identify expert versus novice understanding within a given knowledge domain (Ruiz-Primo & Shavelson, 1996). Concept maps can also be effectively incorporated into university-level teaching as assessment tools to evaluate student understanding (Jacobs-Lawson & Hershey, 2002; Novak and Gowin, 1984).

Pedagogical content knowledge (PCK) is a form of knowledge that makes scientist a science teacher (Gudmundsdottir, 1987). PCK represents the blending of content and pedagogy into an understanding of how particular aspects of subject matter are organized, adapted, and represented for instruction. The aim of the present paper is to determine student teachers' perceptions of pedagogical value of a serious game about plant ecology using concept maps as an assessment tool to evaluate students' understanding of pedagogical value of the serious game. We evaluated the perceptions of participating students from Czech Republic, Ireland and Slovenia, all students were in primary or post-primary teacher education. The groups of students from different countries were used as a model on how to use concept maps as an assessment device to evaluate students' understanding of pedagogical value of the serious game. We had no intention to do a detailed cross-cultural comparison of the results.

Methodology

Description of the serious game Extinct – plant survival

The game used in this study was the serious game "Extinct" by Patrick Middleton (http://www.bbsrc.ac.uk/engagement/schools/keystage4/extinct/) This is a plant survival game which is on-line, downloadable and free (Figure 1 and 2). This serious game is for ages 14 – 16. The game has two strategies, the first is to survive as a wild plant and the second is to survive as a crop plant. Players must decide to grow roots to get water and minerals, to grow leaves for photosynthesis and thus have energy for growth and development, and to grow flowers for pollination by insects. All processes are needed and players must consider the season and the environmental conditions. The aim of the first strategy is produce and disperse as many seeds as possible in order to survive to the next season and the aim of second strategy, as crop plant, is to produce as many big seeds as is possible. If the player fails to discover the best strategies for plant survival he or she gets feedback during the game which informs them how to improve it in order to increase the plant's survival. The player is kept updated throughout the game about environmental conditions (e.g. rain, sunshine) and can keep an update on the amount of sugars and minerals available to »build« the plant.

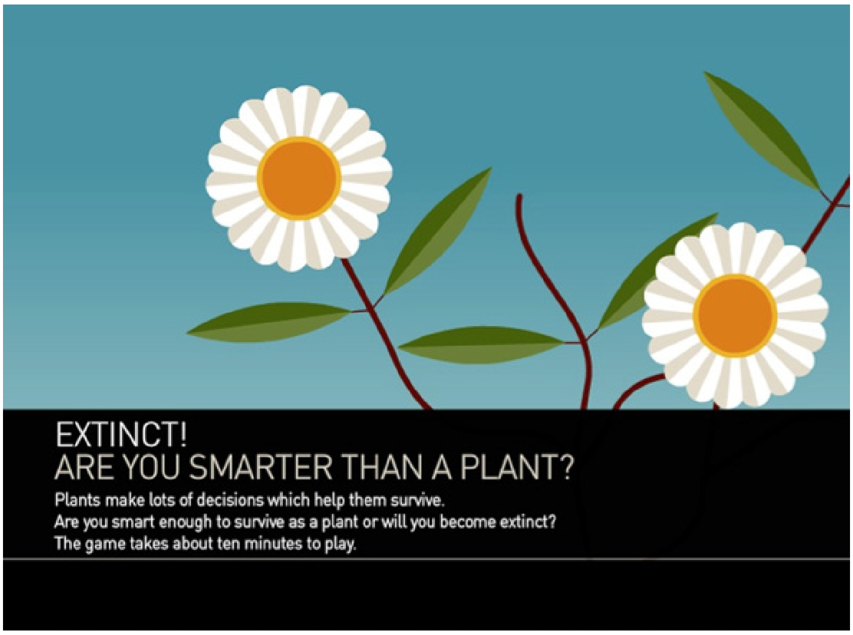

Figure 1. Screenshot from the game – Extinct

Figure 2. Screenshot from the game – Extinct

Research design

The activity was implemented in school year 2015/16. Students were assigned to play the "Extinct – plant survival" game in a computer room. First, in tutorial, a facilitator explained how the game is played by demonstrating on the computer how to operate at the starting levels (months). The facilitator emphasized that the aim of the game is to survive as a wild plant and produce and disperse as many seeds as possible. Next, students had to play the game individually six times or less if they scored 75% chance of passing wild plant genes on to the next generation. On average, a student needed ten minutes to play the game. Each student was given a template to record the scores (no. of seeds, % chance). A week later, students got basic instructions on how to fill in the questionnaire and an hour long Powerpoint presentation was given on how to make concept map. After that, each student was asked to make a concept map based on the statement "what school topics/concepts can students learn while playing this game?" They could draw their concept map free-hand or use the digital resource Cmap Tools (http://cmap.ihmc.us/). Then they answered to some open-ended questions related to the activity. Only results for the question “How student teachers would use the game in their classroom?” are presented and discussed.

Participants

The participants consisted of male and female students between the ages of 19 to 39. Altogether, 65 Primary or Post-primary teacher students participated in the study; 32 students from Czech Republic, 18 from Ireland and 15 from Slovenia (Table 1).

Table 1. *Details about participating students*

Country	Number of students	Study program	Year of study
Czech Republic	32	Primary Teacher Education (Master’s degree) - 6 students Post-primary (Second-level) Teacher Education (Master’s degree)* - 26 students	1st year – 17 students 2nd year – 15 students
Ireland	18	Primary Teacher Education (Bachelor’s degree) - 18 students	2nd year – 18 students
Slovenia	15	Post-primary (Second-level) Teacher Education (Bachelor’s degree)* - 15 students	2nd year – 5 students 3rd year – 10 students

* For all participating post-primary teachers, biology was one of two specialized subject areas.

Students wishing to become primary or post-primary (second-level) teachers can begin their third-level education directly from second-level. In Ireland, primary teachers take a four year Initial Teacher Education leading to a Bachelor of Education degree and post-primary teachers can take a consecutive or concurrent degree in the subject content and Education leading to appropriate Bachelors degree with Education. Alternatively, students may take a full undergraduate degree and then enrol in a Professional Masters in Education (PME) programme which is two-years in duration. In Czech Republic and Slovenia primary teachers take a five-year Primary Teacher Education leading to a Master of Education degree. And post-primary teachers take a degree in two subject areas (e.g. two-subject teacher of biology and chemistry) leading first to appropriate Bachelors degree (3 or 4 years in duration) and compulsory continuation on Master level (1 or 2 years in duration).

Data analysis

Four stages of scoring student’s concept maps were applied. First, the number of relationships between concepts, indicated by the connecting line and linking word(s) forming a statement, was counted. If the relationship was meaningful and scientifically valid we counted them with the code RE1. Nonvalid (e.g. misconceptions) relationships were coded as RE2. Next, we focused on the hierarchy of concepts. Levels were counted from key concepts down through more subordinate concepts. Subordinate concepts are less general and more the ideas developed through the hierarchical levels. The total (maximum) number of valid levels of hierarchy in the student’s concept map was counted (code HC). The number of meaningful connections between one segment of the concept map and another (domains of knowledge) we counted as cross-links (code CL1). We separately counted the number of cross links that were incorrect and did not illustrate a synthesis between segments or sets of related concepts (code CL2). An example of scoring is illustrated in Figure 3.

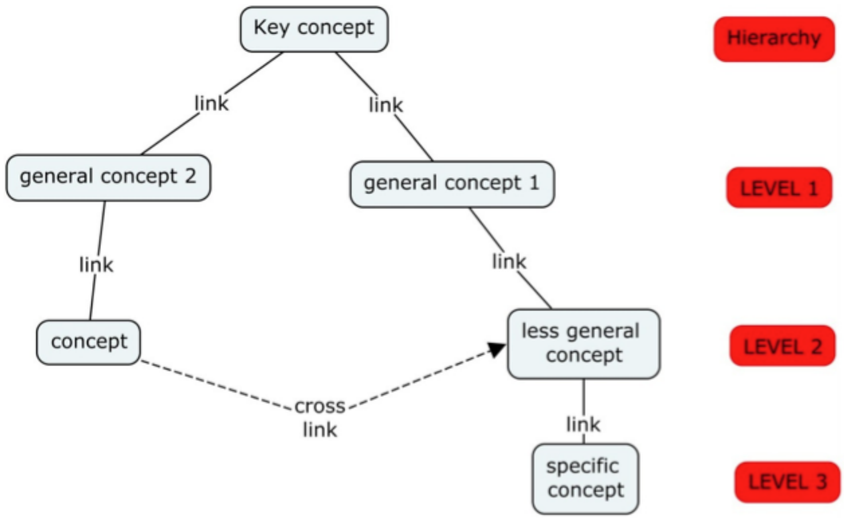

Figure 3. Scoring of student's concept map (relationships (RE1) (counted number of valid links) – 5; hierarchy (HC) (see in red) – 3; cross links (CL1) – 1)

In the fourth stage we made a criterion concept map (summative map) that includes a great majority of concepts and relations created by students (Figure 4). The map was used as the criterion for evaluating students' individual maps. We wrote down which topics a student emphasized in their concept maps (e.g. plant parts, growing factors, reproduction) (code CCM1). Next, the total number of concepts used in the map was counted. Each used concept counted only once, if a student used it more than once (code CCM2). Detected misconceptions or unsatisfactory knowledge of concepts/processes represented in concept map were also recorded (CCM3).

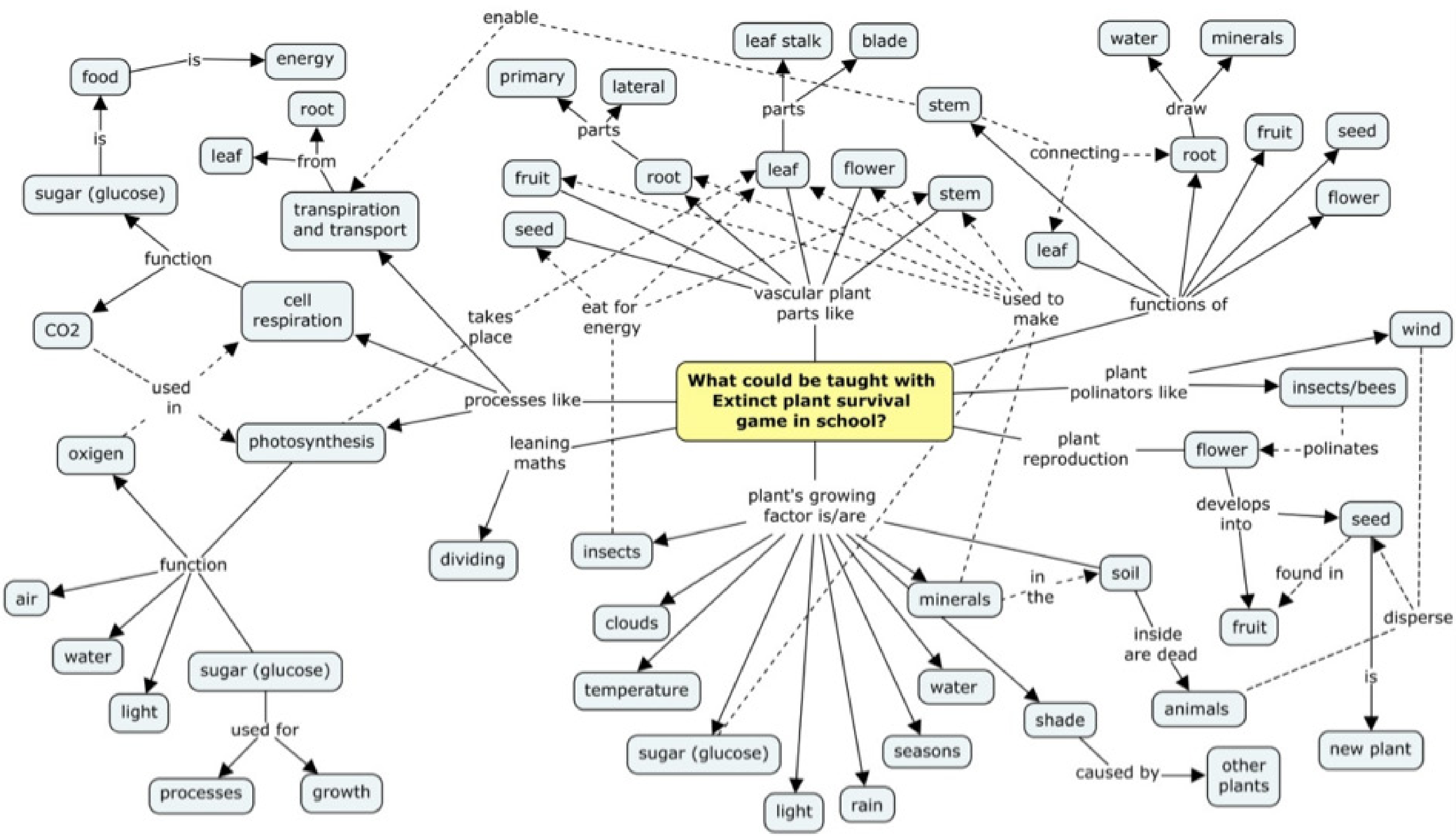

Figure 4. Criterion concept map

Results and Discussion

Students' ideas on what could be taught with this game

Participating primary or post-primary teacher students made their concept maps on what could be taught with the Extinct – plant survival game. Tables 2-4 describe the descriptive statistics for analyzed concept maps. Figures 5–11 contain frequencies for all the students and separately for students from each country (Czech Republic – CZ, Ireland – IE and Slovenia – SI).

On average, participants could correctly form 20.89 (SD=10.09, min=6, max=50) meaningful and scientifically valid relationships between concepts in the concept maps (RE1). Figure 5 shows that relationships were most frequent among students from Czech Republic. Participating students made on average less than one non-valid (RE2) relationship between concepts (M=0.90, SD=1.67, min=0, max=9). Non-valid relationships between concepts were more common among Irish and Slovene students (Figure 5), which can partly explain results presented in Figure 5, where Czech students had more valid relationships between concepts.

Table 2. *Descriptive statistics for valid (RE1) and non-valid (RE2) relationships between concepts*

		N	Mean	SD	Min	Max
RE1	CZ	32	26.03	10.419	8	50
	SI	15	14.33	3.735	8	21
	IE	16	16.75	8.136	6	39
	Total	63	20.89	10.095	6	50
RE2	CZ	32	.31	.965	0	5
	SI	15	1.13	1.807	0	7
	IE	16	1.88	2.187	0	9
	Total	63	.90	1.672	0	9

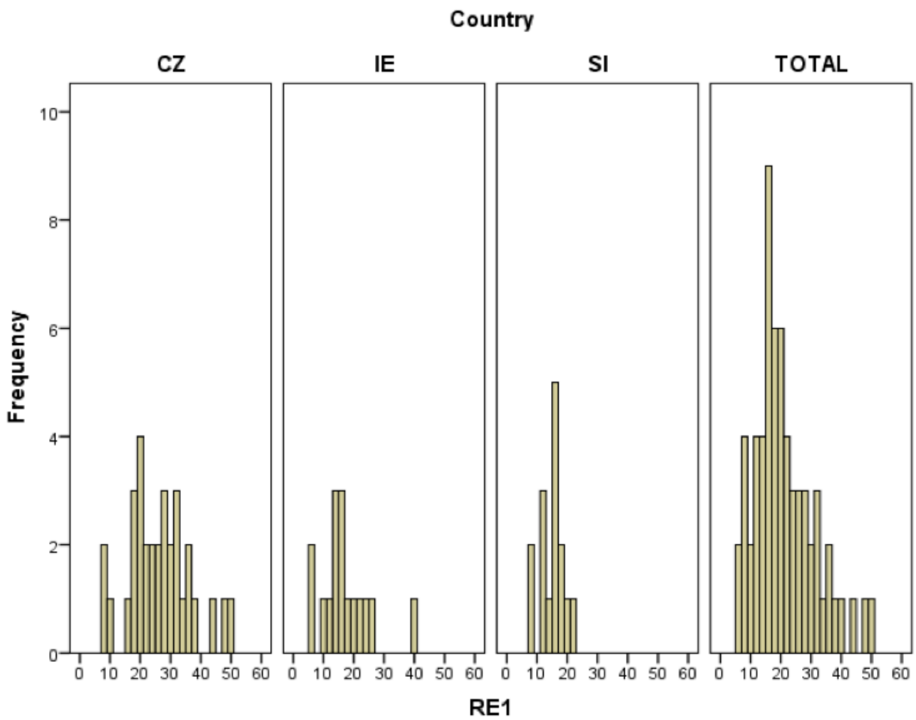

Figure 5. Valid relationships between concepts (RE1).

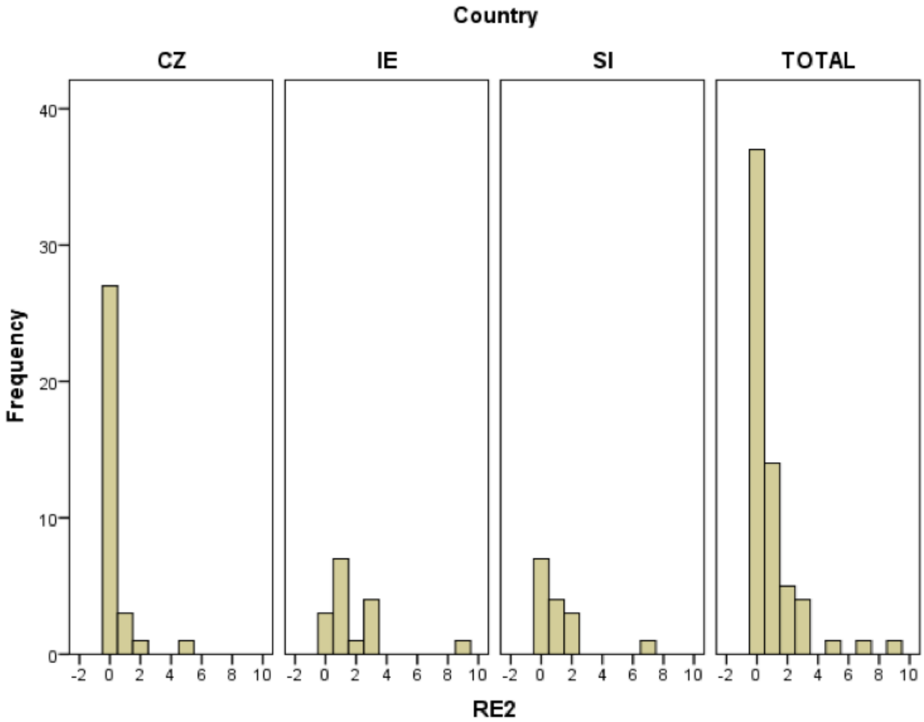

Figure 6. Non valid relationships between concepts (RE2)

A concept map is a hierarchical display of propositions that connect important concepts. We were interested to know how many hierarchical levels students used. On average, participants used three valid levels of hierarchy in the concept map (M=2.97, SD=.80) and maximum five levels (Table 3). Figure 7 shows that students from Slovenia sort out the concepts using the smallest number of levels. We counted a number of valid cross links between one segment of the concept hierarchy and another (CL1). Results show that an average number of valid cross links between one segment of the concept hierarchy and another is 2.32 (SD=2.191, min=0, max=10). The number of valid cross links is much higher among Slovene students than other students. This partly explains why they used less levels of hierarchy in their concept maps. It also shows their ability to integrate concepts. As explained by Ruiz-Primo and Shavelson (1996) the cross-links represent integration between subdomains within the knowledge hierarchy. We counted a number of non-valid cross links between one segment of the concept hierarchy and another (CL2). Table 3 and Figure 9 show that non-valid cross links were very rare.

Table 3. *Descriptive statistics for valid levels of hierarchy (HC), valid (CL1) and non-valid (CL2) cross links between one segment of the concept hierarchy and another*

		N	Mean	SD	Min	Max
HC	CZ	32	3.13	.751	2	5
	SI	15	2.73	.799	2	4
	IE	16	2.88	.885	1	4
	Total	63	2.97	.803	1	5
CL1 valid	CZ	32	1.78	1.560	0	7
	SI	15	3.40	3.019	0	10
	IE	16	2.38	2.125	0	9
	Total	63	2.32	2.191	0	10
CL2 non valid	CZ	32	.03	.177	0	1
	SI	15	.67	1.397	0	4
	IE	16	.56	.727	0	2
	Total	63	.32	.820	0	4

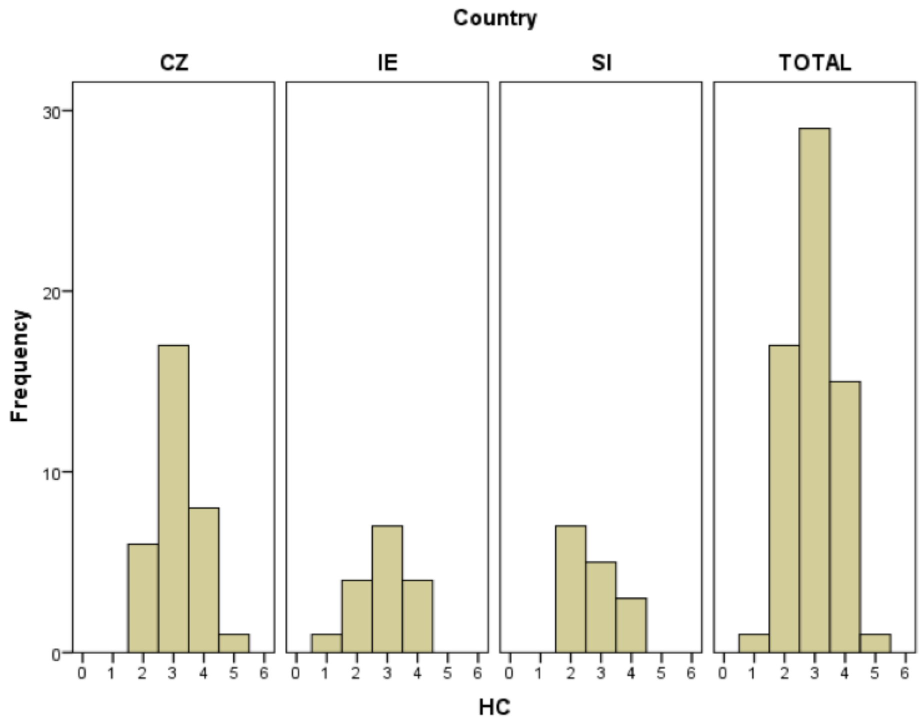

Figure 7. Valid levels of hierarchy in the concept map (HC)

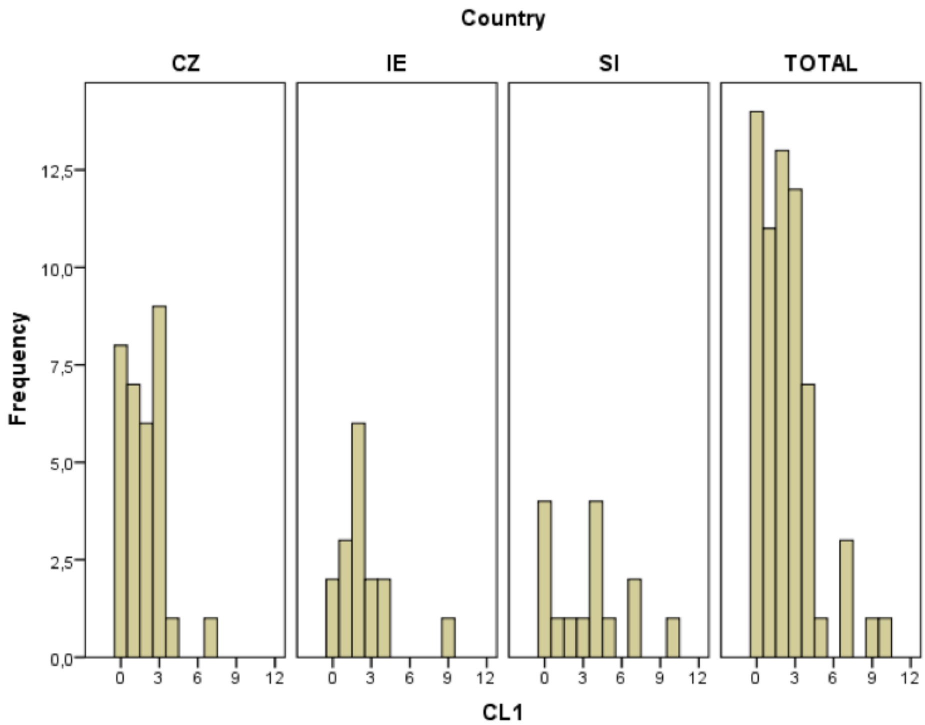

Figure 8. A number of valid cross links between one segment of the concept hierarchy and another (CL1)

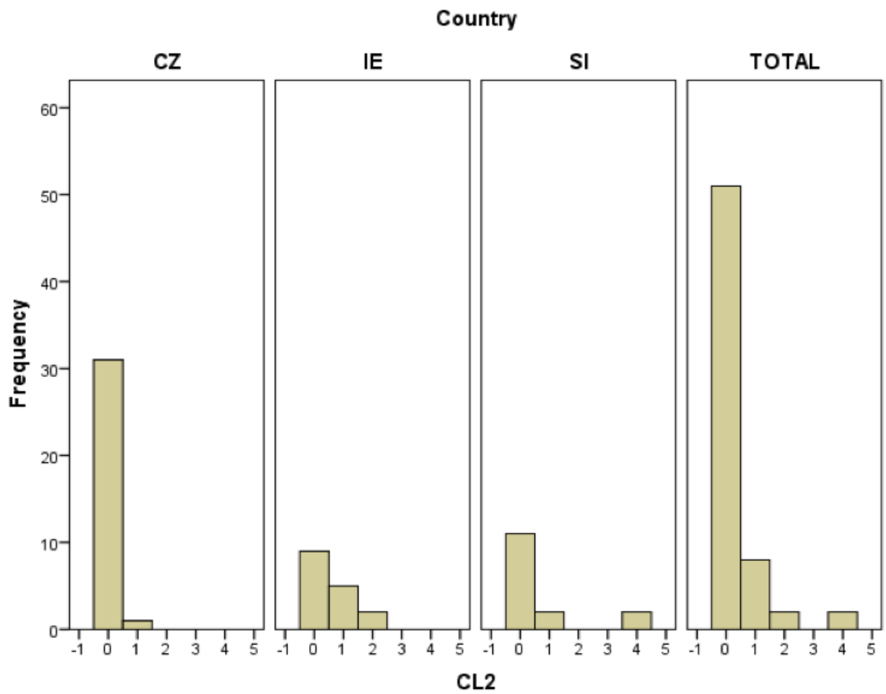

Figure 9. A number of non-valid cross links between one segment of the concept hierarchy and another (CL2)

The created criterion concept map (summative map) that includes a great majority of concepts and relations created by students (Figure 4) was used as the criterion for evaluating students' maps. We identified eight major topics (knowledge domains) in their concept maps: vascular plant parts and functions, processes in plants (photosynthesis, cell respiration), growth factors, reproduction, pollination, agriculture, and herbivores. We counted how many each individual student mentioned (CCM1). Table 4 shows that participants' concepts and relationships were on average classified into 2.87 topics (SD=.98, min=1, max=6). Vascular plant parts and functions (75.0%), processes in plants (e.g. photosynthesis, cell respiration) (62.5%), and growth factors (53.1%) were the most commonly identified topics that could be taught with this game. The Irish students also expanded into other topics such as the effects of seasons and animals on plant growth. These all fit well within the primary science curriculum for senior classes (NCCA, 1999). Percentages for the topics, vascular plant parts and functions, and processes in plants are higher than average among students from Slovenia and Czech Republic, which was expected since the majority of them are students of post-primary teacher education. Post-primary biology curricula emphasize more plant morphology and physiology.

The criterion concept map was also used to count the total number of concepts used in the map (CCM2). On average, 21.67 (SD=9.63) different concepts were used in students' concept maps (Table 4). Results show that students from Czech Republic used more different concepts in their maps (Table 4, Figure 11).

Table 4. *Descriptive statistics for number of knowledge domains used (CCM1), and number of concepts used per map (CCM2)*

		N	Mean	SD	Min	Max
CCM1	CZ	32	2.69	.965	1	5
	SI	14	2.93	.829	1	4
	IE	16	3.19	1.109	1	6
	Total	62	2.87	.983	1	6
CCM2	CZ	32	27.44	9.804	11	47
	SI	15	15.73	3.615	7	21
	IE	16	15.69	5.275	7	29
	Total	63	21.67	9.627	7	47

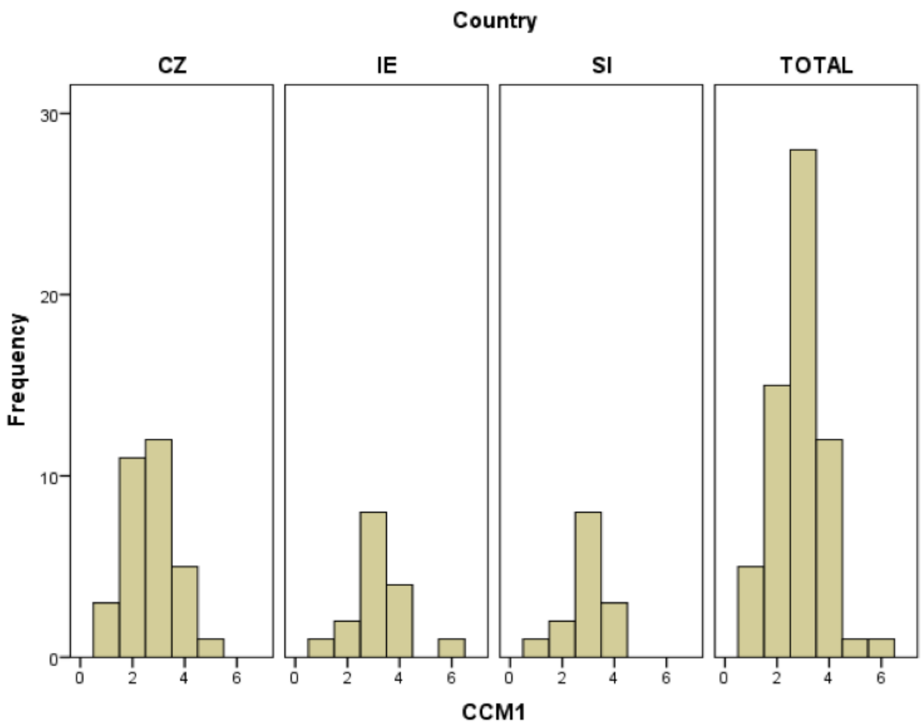

Figure 10. A total number of topics in concept maps (CCM1)

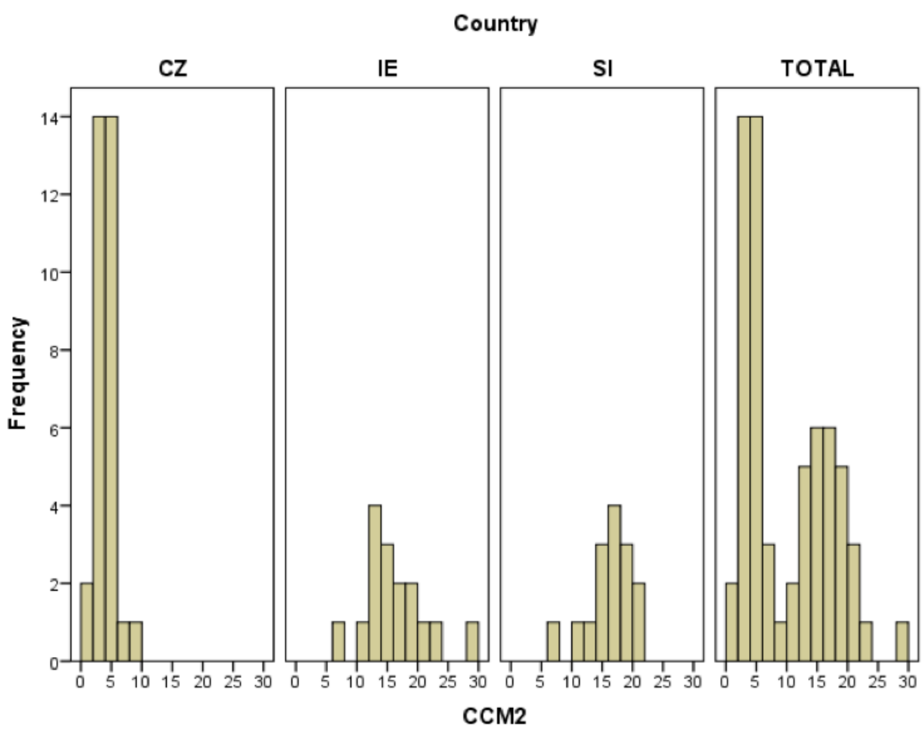

Figure 11. A total number of different concepts used in concept maps (CCM2)

Misconceptions or unsatisfactory knowledge of concepts used in concept maps

Students in general had appropriately developed propositions. However, some misconceptions or unsatisfactory knowledge of concepts represented in concept maps were detected. Three students linked concepts together with no or few linking words, thus generating more of a mind map than a concept map. Those were excluded from further analysis. There were several repeated propositions in multiple maps which indicated general misconceptions. These misconceptions fell into three broad categories:

general anatomy and development of reproductive plant parts, the role of animals in plant reproduction, and energy conversion during photosynthesis. There were two students that made incorrect comments regarding the development of flowers, with one stating they were modified stems and another that they developed from leaves. Both students were students of primary teacher education. Two students suggested that fruit became seeds. The most common misconception overall was that pollination led to seed dispersal. Six students made this statement directly and the steps between pollination and seed dispersal (i.e. seed development) was overlooked. Two students suggested that the role of bees was seed dispersal and there were several students who did not fully develop the concept of animal dispersal of seeds or fruit and there was some ambiguity around the role of bees versus other animals. These concepts are intricately linked, from flower development through fertilization via pollination resulting in seed production, fruit development and dispersal by animals. The second most common misconception was that sunlight produced or made energy. In addition, there was some confusion around the production of oxygen and carbon dioxide with one student suggesting animal decay resulted in O_2 as a waste product and another student suggesting that CO_2 was a product of photosynthesis. Three students did not name all the products of photosynthesis, emphasizing only oxygen as a product. It was also clear that two or three students were confusing climate and weather based on their written responses regarding what school topics they could teach. Most of these concepts were not clearly identifiable in the game and indeed the game itself could lead to some of these misconceptions if the students did not have the prior knowledge.

How student teachers would use the game in their classroom

Certainly, when asked how students would use the game in their classroom, the majority stated that they would use it as a recap, after they had taught the necessary information. Seven of them stated they would use it to initiate learning, although three also stated they would start with the game to assess prior knowledge. Five participating students suggested this game would work well as an assessment tool and two suggested using it as a virtual experiment.

Some teachers' statements:

> *"I would use this game within the framework of the school project day or as activity at the end of a school lesson or as homework." (Czech post primary teacher)*

> *"I would use the game to teach science and biology. Pupils would play the game at home and thus consolidate the knowledge they gained in school lessons. I would not use it in the school lesson." (Slovene post primary teacher)*

> *"I really enjoyed doing this game as it is a fun exercise but it also teaches you about plants and the essential amount of nutrients/sun/Co2 it needs to stay alive. I would definitely use it in the science curriculum under the 'living things' strand. When teaching about the life cycle of plants, I believe it would be appropriate to introduce the game. I could use the game on the powerpoint, then get the children to work on it in pairs and the finish on their own at home." (Irish Primary teacher)*

> *"I would use this game as a motivation. When repeating the curriculum." (Czech post primary teacher)*

> *"While playing the game, pupils will be introduced to the structure of the plants, what they need for growth and development and the process of photosynthesis." (Slovene post primary teacher)*

> *"I wouldn't see any reason not to use this game. It's fun, engaging and educational, in other words, the perfect school activity." (Irish primary teacher)*

Conclusions and implications for teachers

The use of serious games can be an engaging way for students to learn valuable content knowledge while also developing scientific skills. The success of these games in increasing pedagogical content knowledge, however, is determined by the teachers' ability to utilize the game in a constructive manner and apply the game to curriculum learning objectives. All student teachers (both primary and post-primary) who participated in this research agreed that they could use this game in their classroom. They could recognize the pedagogical value of the game and found multiple curricula topics such as: vascular plant parts and functions, processes in plants (photosynthesis, cell respiration), growth factors, reproduction, pollination, agriculture, and herbivores where the game may be of use.

Concept maps can be an effective research tool and were utilized in this study. Overall, concept maps from all participants could be compared and pooled as they fell generally within the same ranges. Only mind-maps (with no linking words used at all in propositions) or intelligible maps were removed from assessment. The majority of differences detected were in the number of concepts used, the valid relationships between concepts, and the cross links between one segment of the concept hierarchy and another. In addition, different students would highlight or identify different topics from each other and no student met all eight major topics as identified in the criterion map. Although an in-depth analysis was not conducted between countries or demographic parameters due to sample size, some of these differences appeared to be country specific. This may be related to differences in curriculum focus (such as taxonomy and biodiversity versus processes and systems) or it may be a result of differences in student teacher background knowledge (second degree, science majors versus primary degree, non-science majors) or year of study (Master's degree or final year of study versus first degree second year students). It would be interesting to determine the role of these elements in determining student teacher focus and concept development when using serious games in their lesson planning.

Specific misconceptions about relevant concepts were also identified through this study. Concept maps use for the assessment of understanding and identification of misconceptions has been shown to be effective (Van Zele, et al., 2004). Our case study reinforces the use of this methodology to identify both accurate and inaccurate conceptual knowledge within a given topic. Concept maps are an effective research tool but can also be used as a means of formative assessment in the classroom. They can be used to gage the development of concepts and identify both the successful understanding and areas of weakness that may require additional learning support.

This study was part of a larger project which looked at the potential use of serious games in the classroom (Erasmus+ Tealeaf). In this project, participants investigated various ways of using serious games in the classroom. A teachers book is published (LINK) which presents some of these games as activities to construct new knowledge and understanding about biological topics in the school setting. The focus of the Tealeaf project was to develop teachers' competences in making and using serious games. In the case of the game Extinct, most student teachers who participated in this case study stated that they would use this game primarily as a support or reinforcement of the material taught, as a recap of the lesson. Several stated they would use it as a trigger at the beginning of a lesson or to assess prior knowledge. In addition, although the game was targeted for ages 14 – 16, primary teachers recognized the use of this game in higher primary classes, thus the game has a wider reach than identified. This suggests teachers should try a serious game out and determine for themselves the potential pedagogical value for their class, consider their specific curriculum objectives that may be underscored through the playing of the game and the interest the game may evoke in their students regardless of the games ranking or general description.

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