Management of Biological Invasions (2021) Volume 12 **Article in press**

Special Issue: Proceedings of the 21st International Conference on Aquatic Invasive Species
Guest editors: Sarah Bailey, Mattias Johansson, Brenda Koenig and Linda Shaw

CORRECTED PROOF

Education and Outreach

Novel tools and best practices for education about invasive alien species

Laura N.H. Verbrugge[1,2,*], Murray I. Dawson[3], Lyn A. Gettys[4], Rob S.E.W. Leuven[2,5], Hélia Marchante[6,7], Elizabete Marchante[7], Petri Nummi[1], Annerie H.M. Rutenfrans[8], Katrin Schneider[9] and Sonia Vanderhoeven[10]

[1]*University of Helsinki, Faculty of Agriculture and Forestry, Department of Forest Sciences and Helsinki Institute of Sustainability Science, P.O. Box 27 (Latokartanonkaari 7) FIN-00014, Finland*
[2]*Netherlands Centre of Expertise for Exotic Species (NEC-E), Nijmegen, The Netherlands*
[3]*Manaaki Whenua – Landcare Research, P.O. Box 69040, Lincoln 7640, New Zealand*
[4]*University of Florida, Fort Lauderdale Research and Education Center, 3205 College Avenue, Davie, FL, 33314, USA*
[5]*Radboud University, Institute for Water and Wetland Research, Department of Animal Ecology and Physiology, P.O. Box 9010, 6500 GL Nijmegen, The Netherlands*
[6]*Instituto Politécnico de Coimbra, Escola Superior Agrária, Bencanta, 3045-601, Coimbra, Portugal*
[7]*University of Coimbra, Centre for Functional Ecology, Department of Life Sciences, Calçada Martim de Freitas, 3000-456, Coimbra, Portugal*
[8]*Adviesbureau Beleef en Weet, Hermelijnstraat 53, 6531 JW Nijmegen, The Netherlands*
[9]*Coordination Centre for Invasive Plants in protected areas of Saxony-Anhalt at UfU – Independent Institute for Environmental Issues, Gr. Klausstrasse 11, D-06108, Halle/Saale, Germany*
[10]*Belgian Biodiversity Platform, Département du Milieu Naturel et Agricole – Service Public de Wallonie Avenue Maréchal Juin, 23 B-5030 Gembloux, Belgium*

Author e-mails: *lauraverbrugge1@gmail.com (LV), dawsonm@landcareresearch.co.nz (MID), lgettys@ufl.edu (LAG), r.leuven@science.ru.nl (RSEWL), hmarchante@esac.pt (EM), beleefenweet@glazenkamp.net (AHMR), katrin.schneider@ufu.de (KS), s.vanderhoeven@biodiversity.be (SV)*

**Corresponding author*

Co-Editors' Note: This study was contributed in relation to the 21st International Conference on Aquatic Invasive Species held in Montreal, Canada, October 27–31, 2019 (http://www.icais.org/html/previous21.html). This conference has provided a venue for the exchange of information on various aspects of aquatic invasive species since its inception in 1990. The conference continues to provide an opportunity for dialog between academia, industry and environmental regulators.

Citation: Verbrugge LNH, Dawson MI, Gettys LA, Leuven RSEW, Marchante H, Marchante E, Nummi P, Rutenfrans AHM, Schneider K, Vanderhoeven S (2021) Novel tools and best practices for education about invasive alien species. *Management of Biological Invasions* 12 (in press)

Received: 15 January 2020
Accepted: 11 August 2020
Published: 28 October 2020

Handling editor: Brenda Koenig
Thematic editor: Sarah Bailey

Abstract

Increasing public awareness is a prerequisite for successful management of invasive alien species (IAS). Environmental education can play an important role in this process by providing relevant learning outcomes and experiences for youth and students, as well as professionals in different sectors associated with introduction pathways or who are involved in mitigation and eradication of IAS. This paper responds to the urgent call for the inclusion of the IAS topic in education through the development, implementation and evaluation of novel and user-friendly educational materials. The aim of this paper is to describe best practices in IAS education and to share the lessons learned from eight educational projects from seven different countries. We discuss four challenges for IAS education, related to (1) inconsistent and ambiguous terminology, (2) communicating risk, (3) implementation of education materials, and (4) evaluation of learning effects. Examples of best practices are the use of smartphone applications and gaming elements, place-based education and exhibitions. We also note the importance of open access publishing of education materials to make them easily available. We intend this discussion to serve as a source of inspiration to researchers, science communicators and teachers and to spur the development of new teaching materials worldwide.

Key words: communication, citizen science, environmental education, non-native species, outreach, public awareness, weeds

Introduction

Increasing public awareness is a prerequisite for successful prevention, control and impact mitigation of invasive alien species (IAS) (Wittenberg

and Cock 2001; Novoa et al. 2017). Numerous examples from practice highlight this urgency. For instance, raising public awareness was a useful tool for the early detection and successful eradication of longhorned beetles (*Anoplophora chinensis* and *A. glabripennis*) in Italy (Ciampitti and Cavagna 2014), as well as giant salvinia (*Salvinia molesta*) in Portugal, after its detection by a group of young students aware of the IAS problems after classroom lessons (Marchante et al. 2018). Likewise, many efforts are put into public awareness campaigns to prevent the introduction of the brown marmorated stinkbug (*Halyomorpha halys*) to New Zealand (Ballingall and Pambudi 2017) or to reduce the risk of spreading invasive aquatic species by boat users in lakes in the United States (Cole et al. 2019). In addition, control and eradication of a species can only be successful if new introductions are prevented (Van Kleef et al. 2008) and sufficient public support is assured (Novoa et al. 2017). Awareness raising comprises several key elements, including species identification skills, and knowledge of invasion processes, introduction pathways, potential effects, and potential management options (Caffrey et al. 2014; Piria et al. 2017; Hulme et al. 2018). This requires awareness and knowledge among the key actors concerned by or involved in the introduction, spread and management of IAS, including:

- Policy makers and local, regional and national authorities who are responsible for implementing regulations, border control and IAS reporting;
- Nature and water managers who are increasingly confronted with new infestations of IAS and management tasks;
- Professionals working outdoors (e.g. landscapers, soil transporters and municipal gardeners as well as biologists, agronomists, rangers and foresters);
- Retailers and traders of (aquatic) plants and animals (e.g. garden centers and pet shop owners);
- General public who can help to prevent new introductions or spread of species, support IAS management, and play an important role in early detection and monitoring of IAS (e.g. citizen scientists and volunteers in nature conservation).

A lack of awareness in any of the key actor groups may result in ineffective management strategies (Davies 2016; Hulme et al. 2018). Previous studies reported low levels of knowledge on IAS among plant and pet retailers (Vanderhoeven et al. 2011; Verbrugge et al. 2014; Oele et al. 2015), even in countries with stringent biosecurity procedures such as Australia (Morrisey et al. 2011). In contrast, a study in Switzerland found rather high levels of awareness among horticulturists, probably due to their personal involvement in drafting national IAS regulations (Humair et al. 2014). The same holds for New Zealand, where plant nursery producers contribute to the National Pest Plant Accord, a cooperative agreement

between the nursery industry, regional councils and government departments with biosecurity responsibilities (Newfield and Champion 2010). However, in many cases, professionals or retailers will not have this experience, especially not when legislation is designed and implemented in a rather top down fashion, as is the case with the EU-regulation 1143/2014 on prevention and management of IAS. There is thus an urgent need to educate students and professionals in the different sectors associated with IAS about pathways and species management (Wittenberg and Cock 2001).

Initially, environmental education aimed at "*producing a citizenry that is knowledgeable concerning the biophysical environment and its associated problems, aware of how to help solve these problems and motivated to work toward their solution*" (Stapp 1969, pp. 30–31). More recent understandings of this field emerged in the context of sustainability issues. Wals et al. (2014) re-emphasize the importance of converging science education, which is focused primarily on teaching knowledge and skills, and environmental education, which stresses the incorporation of values and changing behaviors. Others point to the importance of the natural world as a key resource for learning and development, such as proximity to nature areas and schoolyards (Leuven et al. 2018; Kuo and Jordan 2019).

The topic of biological invasions is relatively new and it has only recently come to the attention of environmental educators. As such, it is still finding its way into courses and textbooks. Moreover, teachers may have limited knowledge about (or may even be unaware of) the subject themselves. To support the inclusion of IAS in education, either in formal or informal contexts, we need to develop, implement and evaluate novel, user-friendly educational materials and tools. This need is recognized at an international level: UNESCO's recent report on issues and trends in education for sustainable development includes invasive species in their learning objectives on threats to biodiversity, alongside habitat loss, deforestation, fragmentation and overexploitation (Leicht et al. 2018). Moreover, EU Member States are expected to promote education about and raise public and stakeholder awareness of the causes of biological invasions and the risks associated with the introduction of IAS (Davies 2016). While this task has been taken up by several organizations in different countries (e.g. Brunel 2014; Davies et al. 2016), their efforts often remain fragmented, uncoordinated and/or undocumented.

The aim of this paper is to share and discuss best practices and lessons learned on how to address specific challenges in raising awareness about IAS in a broad educational setting, including schools and educational settings outside the classroom (e.g. natural history museums). For this exercise, we draw on concrete examples of novel tools and methods used in IAS educational projects globally, including case studies from Europe, North America and New Zealand.

Methods

Discussions during previous editions of the International Conference on Aquatic Invasive Species (ICAIS) sparked the initial interest to identify themes and best practices across educational projects on IAS. Here, we evaluate eight educational projects on IAS from seven countries: AlterIAS (Belgium), ECOSIM and LINVEXO (The Netherlands), KORINA (Germany), Forest Invaders (Portugal), Alien Species Exhibition (Finland), Florida Invasive Plant Education Initiative & Curriculum (United States), and Winning the War against Weeds (New Zealand). We briefly describe each project in Table 1. A list of references and websites for each example is included in the Supplementary material (Appendix 1). The central question that informed our evaluation was as follows: What lessons can we learn from our experiences with developing, implementing and evaluating educational projects about IAS? While doing so, we were interested in both content (i.e. what are the messages?) and form (i.e. how to best deliver the messages?). In the remainder of this paper, we report the major challenges we encountered, offer recommendations to overcome these challenges, and share examples of best practices and novel educational tools.

Results

Challenges

Challenge 1: Terminology

Communicating about IAS to a lay audience can be challenging for several reasons, such as a lack of understanding of key concepts in (invasion) biology and the complexity of social-ecological systems, which introduced species are part of (Davis et al. 2018). Similar challenges emerged from the evaluation of our IAS education projects, in particular related to the ambiguity of definitions and the notion of values incorporated in IAS terms.

The multiple definitions and understandings of what native, alien and invasive species are may be confusing for a lay audience. It requires a basic understanding of these terms, including the fact that not all alien species are invasive and that some native species can be regarded as weedy or invasive. Sometimes invasive species and alien species are erroneously used as synonyms. A clear context and reference frame (e.g. country or even regional perspective), as was employed in our example projects, can help to avoid such unwanted discrepancies. For example, the New Zealand initiative carefully considered the titles and messages of closely related programs to attract both the prospective funders and the target audience attentions. The 2016 “Winning the War against Weeds” changed in 2018 to “The Great Weeds Hunt Aotearoa [New Zealand]” which was divided into “The Great Tradescantia Hunt” to focus on that weed for Auckland (North Island) and “The Great Spartina Hunt” as a keynote species for raising awareness of invasive plants of Canterbury (South Island) watersides. Another strategy

Table 1. Overview of the IAS education projects. Links to available materials and software for each example are available in the Supplementary material (Appendix 1).

Name	Short description
AlterIAS (Belgium)	Aim: to teach basic concepts of invasion ecology and raise awareness about invasive alien plants, and incorporate these themes into existing curricula and professional training. Description: a communication campaign with information sessions at horticultural schools and toolkits for teachers. Organizers: University of Liège–Gembloux Agro-Bio Tech and two horticultural centers. Funding: European Commission (*LIFE+*) and Belgian authorities competent for IAS. Target audience (including age): horticultural students, teachers and professionals (16+) Period: 2010–2013
ECOSIM (The Netherlands)	Aim: to increase knowledge about ecological processes and the cost-effectivity of management measures for aquatic invasive alien species. Description: advanced 3D nature management and conservation simulation game. The pumpkinseed sunfish dilemma module uses ecological modelling principles to predict management effects on population trends of the invasive fish and the native amphibians. Organizers: Crossbill Guides Foundation, in cooperation with Radboud University, Leiden University and Bargerveen Foundation. Funding: Netherlands Food and Consumer Product Safety Authority. Target audience (including age): secondary schools and (applied) universities (16+). Period: 2015–ongoing.
LINVEXO (The Netherlands)	Aim: to increase knowledge and awareness of the impacts of invasive alien species and how to effectively manage them. Description: an e-learning tool with eight species modules, for use in classrooms or by individual students. Each module explains the introduction, spread, impacts and management of the species, as well as how to identify them. Organizers: Netherlands Centre of Expertise for Exotic Species and game developers. Funding: Netherlands Food and Consumer Product Safety Authority. Target audience (including age): secondary school students (14+). Period: 2017–ongoing
KORINA (Germany)	Aim: to improve prevention, early warning, rapid response and mitigation of the spread of invasive alien plants, as part of a broader action plan in Saxony-Anhalt, Germany. Description: indoor and outdoor teaching methods, a card game, an exhibition, identification sheets and an e-learning tool. Organizers: Coordination Centre for Invasive Plants in protected areas of Saxony-Anhalt at UfU. Funding: European Agricultural Fund for Rural Development with co-financing by the federal state Saxony-Anhalt. Target audiences (including age): students (10–18), laypersons, conservationists. Period: 2013–2018.
Forest Invaders (Portugal)	Aim: to increase awareness and knowledge about invasive plants and their threats to forest ecosystems among students of six secondary schools in Central Portugal. Description: brief talks, hands-on activities (e.g. use of taxonomic keys to ID collected plants) and simple scientific experiments (e.g. measuring growth traits and assessing seed viability). Organizers: students (graduation and master), teachers, researchers and technicians from College of Agriculture, Polytechnic Institute of Coimbra. Funding: national agency (Ciência Viva) that promotes public awareness initiatives about Science and Technology in Portugal. Target audience (including age): secondary schools students (15–18). Period: 2013–2014.
Alien Species Exhibition (Finland)	Aim: to increase public awareness of the problems caused by invasive alien species in Finland. Description: exhibition in the Finnish Natural History Museum in Helsinki in 1999. When the exhibition in Helsinki ended, it toured around Finland for almost 20 years in a condensed form) Organizers: teaching staff and PhD students taking a course on Popularization of Science. Funding: University of Helsinki and Finnish Natural History Museum. Target audience (including age): visitors (all ages). Period: 1999 (+20 years).
Florida Education Initiative & Curriculum (USA)	Aim: to provide educators in Florida with the information and resources necessary to teach students about the harmful impacts of some invasive alien plants. Description: lesson plans and other educational materials and activities, teacher workshops, and in-class demonstrations of the curriculum. Organizers: UF/IFAS Center for Aquatic and Invasive Plants and the Florida Fish & Wildlife Conservation Commission's Invasive Plant Management Section. Funding: Florida Fish and Wildlife Conservation Commission and numerous other sponsors. Target audience (including age): science teachers for children aged 8-18. Period: 2006–ongoing.
Winning the War against Weeds (New Zealand)	Aim: to reconnect students with the natural environment by increasing their awareness of weed issues, how to recognize invasive species, and where to get further information. Description: The Winning the War against Weeds and Great Weeds Hunt Aotearoa projects engaged >500 students from 19 schools in 4 regions of New Zealand through hands-on activities. Organizers: Manaaki Whenua – Landcare Research. Funding: government grants for societal engagement with science and technology. Target audience (including age): students from low socio-economic areas and limited engagement in technology ((6–)10–12(–17)). Period: 2016-2019.

to improve understanding of species categorizations is to link invasion stages and ecological impacts of IAS to knowledge of concepts and principles from ecology (e.g. population dynamics, co-evolutionary processes, and other species-environment interactions such as propagule pressure and enemy release). For example, both the Florida Education Initiative and ECOSIM include an extensive glossary with detailed references to ecological concepts and various types of species (e.g. invasive, alien, native and threatened species).

Different perceptions of benefits and costs of invasive species add further complexity. This can make IAS management decisions complex due to competing economic, societal and ecological values (e.g. Novoa et al. 2018), and can result in conflicts of interest. Ethical questions may also arise about controlling charismatic species, especially animal species (Estévez et al. 2015; Shackleton et al. 2019). Teaching about invasive species provides an opportunity to showcase the diversity of invasive species and their impacts but also the diversity in public responses based on different perceptions and values. For example, the LINVEXO tool covers eight invasive species examples, including the zebra mussel (*Dreissena polymorpha*), a species that is now regarded to have both positive (e.g. use of their filtering capacity for mitigating impacts of eutrophication) and negative impacts (e.g. competing with native species) on ecosystems in The Netherlands, and the rose-ringed parakeet (*Psittacula krameri*), a colorful and charismatic bird species that is becoming a common species in urban parks.

Challenge 2: How to communicate risk? What story to tell?

Communicating about IAS is challenging because it involves raising awareness about impacts that are uncertain or difficult to observe. While some species may not yet be present in the environment surrounding the audience, it is still important to make people aware of the potential impacts once a species is introduced. Other species may have impacts that are difficult to notice when you are not specifically trained to do so, for example in aquatic environments or through transmission of parasites and diseases. Moreover, people may not even be aware of which local plants are native or non-native and attitudes towards IAS can fundamentally differ depending on people's values and perceptions of risk (Estévez et al. 2015). As such, messages inherent to biological invasions must be carefully and explicitly addressed, especially where the audience may need to modify its behavior to reduce risk (FAO 2019; Neeley and Devorshak 2012).

Our examples show how the language used in IAS messages can be adapted or reframed depending on the target audience and goals. In some cases, the use of strong or even militaristic language, as in the "winning the war against invasive weeds" project in New Zealand, may make it easier to communicate a clear message or activate younger students. While such

Table 2. Type of messages that were included in the educational projects (BE: Belgium, DE: Germany, FL: Florida, NL: The Netherlands, NZ: New Zealand, PT: Portugal).

Solution and behavior-oriented messages	• Prevention starts in our gardens and ponds (BE, DE, FL, NL) • Let's plant differently (BE, NZ) • Do not use or spread invasive plants and animals (FL, NL, NZ, PT) • Plan or participate in raising awareness initiatives (FL, NZ, PT) • Plan or participate in volunteer control actions (PT) • Map and report invasive plants (DE, FL, NZ, PT) • Which methods can be used to control invasive species? (FL, NL, NZ, PT)
Informative messages	• What are native, alien and invasive species and weeds? (DE, FI, FL, NL, NZ, PT) • How do alien species spread? (DE, FI, FL, NL, NZ, PT) • What are the ecological effects of alien species? (DE, FI, FL, NL, NZ, PT) • What are the socio-economic effects of alien species? (FL, NL, NZ, PT) • How can the effects of aliens be mitigated? (FI, FL, NL) • How can I identify invasive species? (DE, FL, NL, NZ, PT) • What are the main characteristics of invasive plants? (FL, NZ, PT)
Understanding impacts and processes	• How do invasive species affect the growth or abundance of native species? (FL, NL, NZ, PT) • What is the role of human agency in introducing alien species? (DE, FI, FL, NL, NZ, PT) • How is the invasion process structured? (FL, NL, PT)

metaphors may motivate action in the short term, they have also been criticized for their connotations with immigration, racism or xenophobia (Larson 2005). A responsible use of metaphors thus requires reflection upon the ethical and rhetorical dimensions of choices in language when communicating about IAS (Verbrugge et al. 2016), especially in multicultural societies and working with minority groups.

A storyline or narrative approach is useful to adopt as it provides a structure for presenting the problem, actors involved, and potential solutions (Dahlstrom 2014; Enfield 2018). A good preparation tactic is to define three or four key messages that can be clearly communicated. Table 2 gives an overview of the main messages that were employed in the example projects, distinguishing between solution and behavior-oriented messages, informative messages and process-understanding messages. A combination of different types of messages is most effective in educational projects, to improve knowledge and skills and influence attitudes and behaviors.

It is also important to note that there is not a single strategy for conveying these stories to a large variety of audiences. The AlterIAS project in Belgium targeted diverse audiences ranging from secondary school students to horticulture professionals. They discovered that the same general message had to be conveyed to a panel of actors whose basic knowledge of biological processes, technical knowledge, and even learning skills were very different and sometimes difficult to anticipate. Developing a general educational tool was therefore not an option; it was necessary to develop as many different approaches as the target audiences. The involvement of education experts in addition to IAS experts will greatly benefit any project, especially when it comes to transposing the story to appropriate learning techniques.

Challenge 3: Implementing and sustaining educational projects

Environmental education and communication campaigns are costly, both in terms of time and money. The AlterIAS project was awarded a best LIFE-Nature award for its efforts: a total of 71 information sessions in 41 schools, horticultural centers and universities were organized throughout Belgium between 2010 and 2013. However, the authorities in charge of IAS in Belgium have not fixed the human nor financial resources to sustain the AlterIAS educational effort into the future. In the same order, launching similar initiatives dedicated towards other taxonomic groups such as pet or aquaculture species was envisaged but this has not been done. Continuity of funding can thus be hard to obtain, and the effort of applying for funding, developing educational materials and establishing networks is not maximized if there is only short term or limited funding available.

Most of the projects reported difficulties in starting from scratch in developing educational materials without any previous experience working with educators, schools or curriculum. Simple things like illustrated materials or species identification sheets can be very time consuming and costly to make, and must be tailored for the intended audience. This challenge may be overcome if, at the time of development, the materials are planned to be used for a long time period. For example, the Forest Invaders project in Portugal had no resources to print or develop any materials. However, a website about invasive plants (invasoras.pt) and ID guide and bookmarks were developed and designed in a general way, with the benefit that they could be reused for other purposes and increased the project's sustainability.

Collaboration with teachers or other specialists in education is recommended to develop effective and user-friendly programs and tools. The Florida Education Initiative & Curriculum staff worked directly with educators, program evaluators, researchers in the field of invasive plant biology and management, and other experts within the University of Florida community. This requires sufficient preparation time and opportunities for collaboration to accommodate teachers' busy schedules and other needs.

Once a school or individual teacher gets involved, there can be a *multiplier effect* – meaning that teachers who participated will integrate IAS education in their classes and/or plan to continue or expand related lessons in the future. This was the case for the implementation of LINVEXO in The Netherlands where pilot projects at a few locations were scaled up and inspired teachers at other school locations. The facilitation of an online community and the presentation of LINVEXO at yearly staff training events contributed to this by providing them with knowledge and tools they need. The same happened with Forest Invaders in Portugal. Krasny and Lee (2002) refer to this as a social learning approach, i.e. to encourage educators to use their newly acquired knowledge to design programs to meet local needs. Our examples show that collaborative design and implementation support can ensure that IAS education becomes

structurally embedded in educational curricula, guaranteeing the use of these tools on the longer run without additional financial support.

Challenge 4: Evaluating the outcomes

Evaluation is an important but often overlooked element of the development of new educational projects. Evaluation can focus on the effects on learners, from students to professionals, their satisfaction with the lessons, and teacher evaluations. Moreover, evaluations could try to capture a change in learner's attitudes and behavior. Often it is difficult to assign learning to one type of activity, as you evaluate the whole process including external influences. Below, we give two examples of projects that evaluated the learning effects on students and their experiences.

The Forest Invaders project evaluated students' knowledge three months after the last activities took place. A sub-sample of the high-school students, aged 15 to 18 years old, was selected to answer a questionnaire and their answers were compared with a control group from the same schools (but who did not participate in any activity). The findings showed that knowledge about invasive plants increased among students that participated in the lecture and ID activity and even more when field or lab experiments were performed (compared with students that did not participate in the activities) (Marchante et al. 2013). This difference is remarkable as the topic of biological invasions had been part of the formal school curricula in Portugal for at least five years when the project took place.

The e-learning tool LINVEXO was tested in secondary vocational education in The Netherlands using before and after surveys on the same day (Rutenfrans 2018). At the start of the trials, the majority of the students (80%) reported that they did not know about IAS and their environmental impacts. After completing the LINVEXO assignments, 80% of the students were familiar with IAS and their impacts. The evaluation furthermore showed that students as well as teachers highly valued this e-learning tool in a classroom setting.

While both examples show that IAS education enhances students' knowledge of IAS, it is important to note that such evaluations are scarce and require more attention, especially with regards to measuring changes in attitudes and behavior. For example, an increase in knowledge can also have unintentional effects, as evidenced by Krasny and Lee (2002, p. 113) who found that participants' belief in the ability to control IAS decreased after their experience in the program "*perhaps because they became more aware of the enormity of the problem and the limited control options currently available*".

Novel tools and best practices

Smartphone applications

New technologies such as smartphone application software (apps) and social media are increasingly used to engage a wider audience in recording

Figure 1. On the right: Franz Josef Glacier School student recording a European alder (*Alnus glutinosa*) sapling using the iNat app, New Zealand (Photo: Murray Dawson). On the left: High school students measuring tree diameter in an urban park, Portugal (Photo: Hélia Marchante) and the excavation of Bohemian knotweed (*Fallopia bohemica*) during a KORINA science camp, Germany (Photo: Katrin Schneider).

IAS (Adriaens et al. 2015; Figure 1). People nowadays spend significant amounts of time using smartphones and social media, making it a part of everyday life. Smartphone apps can therefore be an effective tool in education, but also to reconnect people with their natural environment (Smith 2013). In Saxony-Anhalt, Germany, the KORINA-App was used during educational modules in schools. The students first learned how to identify invasive alien plants and then went out to record them in the area around the school or in a chosen natural area (Nieke et al. 2018). The records were evaluated by the KORINA team by reviewing the images attached to the app records. Around 90 percent of the recordings were verified. For the students it was very motivating that their records contributed to the control of invasive species.

The amount of preparatory work to use apps in school projects should not be underestimated. It requires a series of actions to create specific online school projects, preinstall the app onto smartphones, and to prepare fact sheets specially designed for the group of invasive species targeted in the activities. It is recommended to leverage on existing technologies whenever possible. For example, Lucid Mobile identification keys and the iNaturalist app have proven highly effective for engaging students in identifying and recording IAS in New Zealand.

Forest Invaders in Portugal also used a mobile app ("Plantas invasoras"), which is part of the citizen-science platform Invasoras.pt (Marchante et al. 2017). Students learned how to use the app and were asked to report the presence of invasive alien plants in their home regions. The app was quite well received among students who registered as users and later submitted some (but frequently not many) IAS sightings to the platform. However, most students (and citizens in general) have no species identification skills and this can be an extra challenge as the first step is to learn to identify IAS. Therefore, in addition to the few species addressed during the Forest Invaders activities, species factsheets and a field guide are available in the website invasoras.pt to support identification.

Place-based education

Local fieldwork is highly effective for raising student awareness of IAS, as exemplified by the following three cases (see also Figure 1). In New Zealand, most school visits included using apps to record weeds growing in school grounds, and local parks and reserves that were within walking distance. In some locations, herbarium specimens were collected and placed in field presses, and new biological control insects were released by the students as part of a wider national release strategy. In Portugal, two fieldwork activities in nearby areas focused on measuring the impacts of IAS at growth parameters of forestry species (using forestry tools to measure plant diameter and plant height) and on methodologies to control invasive plants (e.g. pulling, debarking). These activities were more effective in increasing students' knowledge about IAS than classroom-based activities, as already noted in the section on evaluation. In 2019, LINVEXO was successfully used in a pilot for innovative education on management of urban and green areas, where students were provided with a background of IAS using LINVEXO and subsequently participated in a professional eradication campaign (Rutenfrans et al. 2018).

These examples stress the need to foster educational practices and tools that are place-based in terms of locality and scale. This context dependence is helpful to establish a strong emotive connection to people's identity, self-interest, and values. Situating learning experiences in the places where students live increases their willingness to become engaged in science, citizen initiatives and environmental protection (Smith 2013). In an urban context, where IAS may be more abundant than native species, they can play a role as an "experiential key species" (i.e. a species that can be used to stimulate learning about local ecosystems) with the aim to communicate ecological concepts and conservation issues to children with limited access to nature (Battisti et al. 2018). Within this context, it remains important to focus on local native species to raise community awareness about IAS impacts and the benefits of IAS control (Genovart et al. 2013).

Gaming elements

In the pumpkinseed sunfish (*Lepomis gibbosus*) disaster module of ECOSIM (Crossbill Guides Foundation 2015), students need to find the best way to manage an invasive predatory fish that threatens a native amphibian species. Various management measures can be taken to achieve nature conservation goals and the program enables a competition between students to develop the most cost-effective strategy with limited resources. Such model-based gaming (or "serious gaming") can serve as an appropriate alternative for real world approaches in educational settings. They are designed as experiences that are not only engaging but also increase understanding of various roles and perspectives, as well as the consequences of actions at different points in time (Wu and Lee 2015).

Two universities in The Netherlands (Radboud University and Leiden University) have implemented serious gaming with ECOSIM in their biology curricula and carried out an expert-based SWOT analysis of ECOSIM applications in academic education. Despite the fact that ECOSIM uses a rather simplified ecosystem with a limited number of biotic interactions, they concluded that this serious game is quite realistic and improves the understanding of the complexity of managing socio-ecological systems. It covers all invasion phases (introduction, establishment, spread and impacts) and management measures link to the several stages of this process. Eventually, students come to realize that there are no easy solutions, and that various survey and management strategies are needed to solve environmental problems with IAS.

Exhibitions

Environmental education is not limited to school environments. The aim of the Alien Species Exhibition, held in the Finnish Natural History Museum in 1999, was to increase public awareness of the problems caused by IAS. The exhibition consisted of an international as well as a national part, and included examples of invasive species and ecological processes, such as predation and hybridization. The Finnish part presented alien vertebrates, such as American mink (*Neovison vison*) and brook trout (*Salvelinus fontinalis*), and the numerous invasive alien plants found in Helsinki region. New Zealand was used as an example of very wide scale effects of IAS, and additional cases included rats, ants and water hyacinth (*Eichhornia crassipes*).

The Finnish Natural History Museum is an extremely popular visiting place for school classes and question sheets for three different age classes were prepared to enable IAS learning during the museum visits. The exhibition was combined with a one-day seminar about alien species to target a more general audience and gain press attention. It is important to note the different education outcomes that this project achieved: PhD

students gained knowledge about IAS through designing the exhibition, while the wider audience and schoolchildren could then learn from the displays. The special lectures were useful in spreading information among professionals in policy and management, and led to the drafting of the first national report on alien invasive species in Finland (Nummi 2001).

Promote open access

Lastly, an important task for educators and funders is to produce and fund open educational resources, which can be reused and edited. For example, AlterIAS, KORINA and LINVEXO released short films to enable teachers to use them in the classroom and prevent the common difficulties with usage rights and costs. It is common practice to make educational materials publicly available when funded with public money. However, often there is room for improvement in making these materials easily accessible over a longer period. A good example from our projects is the release of a large number of KORINA images to Wikimedia Commons.

Discussion and conclusion

The aim of this paper was to learn from global experiences in educational projects on IAS and highlight ways to tackle specific challenges in raising awareness about IAS and engaging students. We did not aim to give an exhaustive review but used examples to highlight trends, major challenges and possible solutions. The examples given by the authors of this paper provide a strong representation of teaching materials about freshwater and terrestrial plants (compared to, for example, terrestrial or marine animals). It would be worthwhile to undertake a thorough review to determine the representation of biota and species group(s) in teaching materials and their target audiences.

We discussed the outreach potential of different education approaches including classroom-based activities, field activities and the popularization of science through exhibitions. In general, our examples show that hands-on activities worked better than talks alone and these activities can take place inside and outside of the classroom. One example of an effective hands-on classroom-based activity is using live plant material and identification keys and apps for students to identify and learn more about the invasive plants (instead of only showing pictures in the classroom). For notorious invaders this may not be possible, if regulations prevent the possession and transport of live specimens. Other ways to popularize the topic in the classroom are the viewing of YouTube videos, or referring to local and national media attention for recent introductions or problems with IAS. A combination of tools and approaches is often the most useful approach in education projects. For example, in Saxony-Anhalt (Germany), an exhibition about invasive plants in a local zoo was combined with a

gaming element where visitors were invited to find all featured IAS in the zoo by playing a rally.

It is important to emphasize that teaching about IAS is not limited to biology classes. The topic links to many subjects and themes, such as health and disease, economy, trade, ethics, philosophy, history, geography and art. We would argue that this is a strength and makes IAS a perfect case study, for example as an intractable problem in a sustainability course, as an introduction to fundamental questions on human-nature relationships in an environmental ethics course (Boorse 2004) or to discuss future scenarios of how IAS could shape hometowns (Giese et al. 2014). Here, constructive approaches (i.e. where students and teachers (re)construct knowledge on environmental problems and solutions together) can stimulate reflective, critical thinking (Kyburz-Graber 2013), and knowledge gains and attitude changes are expected to be greater when compared to traditional approaches (DiEnno and Hilton 2005). Biological invasions have also been used in applied contexts outside schoolyards, for instance with experimental designs that allow to evaluate IAS impacts or to control invaded areas by monitoring the recovery of native communities or ecosystem services.

Finally, targeting elementary schools to deliver IAS messages can be an effective method for engaging the wider community. Elementary students are often more receptive than teenagers and adults and will take the IAS messages learnt in the classroom into their homes and communities supporting intergenerational learning (Duvall and Zint 2007; Lawson et al. 2019). Today's students are tomorrow's citizens and young children will take the lessons learnt through to adulthood, which help shape future communities. We hope that our discussion of examples can serve as a source of inspiration to researchers, science communicators and teachers worldwide and promote new efforts in IAS education.

Acknowledgements

We are grateful for the input of Mathieu Halford (AlterIAS), Gregory Mahy (AlterIAS), Solveig Bergholm (Alien Species Exhibition) and Dehlia Albrecht (Florida Invasive Plant Education Initiative). We also express our gratitude to all the students, teachers and other professionals that participated in the projects analyzed in the paper. We also thank four anonymous reviewers for providing their feedback. This article is based upon work from COST Action CA17122, supported by COST (European Cooperation in Science and Technology). EM was funded by Fundação para a Ciência e a Tecnologia through grant UIDB/04004/2020.

References

Adriaens T, Sutton-Croft M, Owen K, Brosens D, van Valkenburg J, Kilbey D, Groom Q, Ehmig C, Thürkow F, van Hende P, Schneider K (2015) Trying to engage the crowd in recording invasive alien species in Europe: experiences from two smartphone applications in northwest Europe. *Management of Biological Invasions* 6: 215–225, https://doi.org/10.3391/mbi.2015.6.2.12

Ballingall J, Pambudi D (2017) Quantifying the economic impacts of a Brown Marmorated Stink Bug incursion in New Zealand: A dynamic computable general equilibrium modelling assessment. NZIER report to Horticulture NZ, July 2017

Battisti C, Fanelli G, Bertolino S, Luiselli L, Amori G, Gippoliti S (2018) Non-native invasive species as paradoxical ecosystem services in urban conservation education. *Web Ecology* 18: 37–40, https://doi.org/10.5194/we-18-37-2018

Boorse D (2004) Teaching environmental ethics: Non-indigenous invasive species as a study of human relationships to nature. *Worldviews: Global Religions, Culture, and Ecology* 8: 323–335, https://doi.org/10.1163/1568535042690862

Brunel S (2014) How to communicate on pests and invasive alien plants? Conclusions of the EPPO/CoE/IUCN-ISSG/DGAV/UC/ESAC Workshop. *EPPO Bulletin* 44: 205–211, https://doi.org/10.1111/epp.12110

Caffrey JM, Baars J-R, Barbour JH, Boets P (2014) Tackling invasive alien species in Europe: the top 20 issues. *Management of Biological Invasions* 5: 1–20, https://doi.org/10.3391/mbi.2014.5.1.01

Ciampitti M, Cavagna B (2014) Public awareness: a useful tool for the early detection and a successful eradication of the longhorned beetles *Anoplophora chinensis* and *A. glabripennis*. *EPPO Bulletin* 44: 248–250, https://doi.org/10.1111/epp.12116

Cole E, Keller RP, Garbach K (2019) Risk of invasive species spread by recreational boaters remains high despite widespread adoption of conservation behaviors. *Journal of Environmental Management* 229: 112–119, https://doi.org/10.1016/j.jenvman.2018.06.078

Crossbill Guides Foundation (2015) Ecosim - Pumpkinseed sunfish dilemma. Crossbill Guides Foundation, Arnhem, http://www.ecosim.nl/node/5 (accessed 22 December 2019)

Dahlstrom MF (2014) Storytelling in science. *PNAS* 111: 13614-13620, https://doi.org/10.1073/pnas.1320645111

Davies P (2016) Alien invasive species: is the EU's strategy fit for purpose? In: Bowman M, Davies P, Goodwin E (eds), Research Handbook on Biodiversity and Law. Cheltenham, UK, pp 184–218, https://doi.org/10.4337/9781781004791.00015

Davies SJ, John Measey G, du Plessis D, Richardson DM (2016) Science and education at the Centre for Invasion Biology. In: Castro P, Azeiteiro UM, Bacelar-Nicolau P, Leal Filho W, Azul AM (eds), Biodiversity and education for sustainable development. Springer International Publishing, Cham, pp 93–105, https://doi.org/10.1007/978-3-319-32318-3_7

Davis E, Caffrey JM, Coughlan NE, Dick JTA, Lucy FE (2018) Communications, outreach and citizen science: spreading the word about invasive alien species. *Management of Biological Invasions* 9: 515–525, https://doi.org/10.3391/mbi.2018.9.4.14

DiEnno CM, Hilton SC (2005) High school students' knowledge, attitudes, and levels of enjoyment of an environmental education unit on nonnative plants. *The Journal of Environmental Education* 37: 13–25, https://doi.org/10.3200/JOEE.37.1.13-26

Duvall J, Zint M (2007) A review of research on the effectiveness of environmental education in promoting intergenerational learning. *The Journal of Environmental Education* 38: 14–24, https://doi.org/10.3200/JOEE.38.4.14-24

Enfield N (2018) Our job as scientists is to find the truth. But we must also be storytellers. The Guardian, 20 Jul 2018, https://www.theguardian.com/commentisfree/2018/jul/20/our-job-as-scientists-is-to-find-the-truth-but-we-must-also-be-storytellers (accessed 22 September 2019)

Estévez RA, Anderson CB, Pizarro JC, Burgman MA (2015) Clarifying values, risk perceptions, and attitudes to resolve or avoid social conflicts in invasive species management. *Conservation Biology* 29: 19–30, https://doi.org/10.1111/cobi.12359

FAO (2019) IPPC guide to pest risk communication. Published by FAO on behalf of the Secretariat of the International Plant Protection Convention (IPPC), 58 pp

Genovart M, Tavecchia G, Enseñat JJ, Laiolo P (2013) Holding up a mirror to the society: children recognize exotic species much more than local ones. *Biological Conservation* 159: 484–489, https://doi.org/10.1016/j.biocon.2012.10.028

Giese K, Schneider K, Herbert C, van Aken T, Wittig S (2014) Invasive Neophyten: Methodenheft für den Biologie- und Geographieunterricht Jahrgangstufen 9-12. Unabhängiges Institut für Umweltfragen e. V., 48 pp, https://www.korina.info/bildung/materialien/methodenheft-klasse-9-12/ (accessed 19 October 2019)

Hulme PE, Brundu G, Carboni M, Dehnen-Schmutz K, Dullinger S, Early R, Essl F, González-Moreno P, Groom Q, Kueffer C, Kühn I, Maurel N, Novoa A, Pergl J, Pyšek P, Seebens H, Tanner R, Touza JM, van Kleunen M, Verbrugge LNH (2018) Integrating invasive species policies across ornamental horticulture supply chains to prevent plant invasions. *Journal of Applied Ecology* 55: 92–98, https://doi.org/10.1111/1365-2664.12953

Humair F, Siegrist M, Kueffer C (2014) Working with the horticultural industry to limit invasion risks: the Swiss experience. *EPPO Bulletin* 44: 232–238, https://doi.org/10.1111/epp.12113

Krasny ME, Lee S-K (2002) Social learning as an approach to environmental education: Lessons from a program focusing on non-indigenous, invasive species. *Environmental Education Research* 8: 101–119, https://doi.org/10.1080/13504620220128194

Kyburz-Graber R (2013) Socioecological approaches to environmental education and research: a pragmatic response to behavioral change orientations. In: Stevenson RB, Brody M, Dillon J, Wals AEJ (eds), International Handbook of Research on Environmental Education. Routledge, New York, pp 23–32

Kuo M, Jordan C (2019) Editorial: The natural world as a resource for learning and development: From schoolyards to wilderness. *Frontiers in Psychology* 10: 1763, https://doi.org/10.3389/fpsyg.2019.01763

Larson BMH (2005) The war of the roses: demilitarizing invasion biology. *Frontiers in Ecology and Environment* 3: 495–500, https://doi.org/10.1890/1540-9295(2005)003[0495:TWOTRD]2.0.CO;2

Lawson DF, Stevenson KT, Peterson MN, Carrier SJ, Strnad RL, Seekamp E (2019) Children can foster climate change concern among their parents. *Nature Climate Change* 9: 458–462, https://doi.org/10.1038/s41558-019-0463-3

Leicht A, Heiss J, Byun WJ (eds) (2018) Issues and trends in education for sustainable development. UNESCO Publishing, Paris, 276 pp

Leuven JRFW, Rutenfrans AHM, Dolfing AG, Leuven RSEW (2018) School gardening increases knowledge of primary school children on edible plants and preference for vegetables. *Food Science & Nutrition* 6: 1960–1967, https://doi.org/10.1002/fsn3.758

Marchante H, Correia A, Oliveira J, Sousa J, Serra V, Couceiro D, Marchante E, Carvalho V (2013) Forest Invaders - the outcomes of a project about invasive species inside and outside the classroom. EPPO/CoE/IUCN ISSG/DGAV/UC/ESAC Workshop "How to communicate on pests and invasive alien plants". Oeiras, Portugal. 8-10 October, https://www.researchgate.net/publication/336919759_Forest_Invaders_-_the_outcomes_of_a_project_about_invasive_species_inside_and_outside_the_classroom (accessed 24 November 2019)

Marchante H, Morais MC, Gamela A, Marchante E (2017) Using a WebMapping platform to engage volunteers to collect data on invasive plants distribution. *Transactions in GIS* 21: 238–252, https://doi.org/10.1111/tgis.12198

Marchante E, Canha P, Vaz AS, Morais MC, Pinto M, Almeida C, Fernandes MR, Graça MS, Figueiredo A, Figueira R, Matos M, Sequeira MM, Pupo A, Marchante H (2018) Prevenção e deteção precoce. In: Vicente JR, Queiróz AI, Silva L, Marchante E, Honrado J (eds), As Invasões Biológicas em Portugal: História, Diversidade e Gestão. Instituto de História Contemporânea, Lisbon, pp 261–290 [in Portuguese]

Morrisey D, Inglis G, Neil K, Bradley A (2011) Characterization of the marine aquarium trade and management of associated marine pests in Australia, a country with stringent import biosecurity regulation. *Environmental Conservation* 38: 89–100, https://doi.org/10.1017/S0376892911000014

Neeley A, Devorshak C (2012) Risk communication in pest risk analysis. In: Devorshak CD (ed), Plant pest risk analysis: Concepts and application. CAB International, pp 199–208, https://doi.org/10.1079/9781780640365.0199

Newfield M, Champion PD (2010) Risk assessment for the New Zealand National Pest Plant Accord: which species should be banned from sale? *Plant Protection Quarterly* 25(2): 75–78

Nieke A, Schneider K, Hollweg F, Schlieker A, van Aken T (2018) Invasive Neophyten: Methodenheft für den Biologie- und Geographieunterricht, Jahrgangsstufen 5-9. Unabhängiges Institut für Umweltfragen e. V., 45 pp. https://www.korina.info/bildung/materialien/methodenheft-5-9-kl/ (accessed 19 October 2019)

Novoa A, Dehnen-Schmutz K, Fried J, Vimercati G (2017) Does public awareness increase support for invasive species management? Promising evidence across taxa and landscape types. *Biological Invasions* 19: 3691–3705, https://doi.org/10.1007/s10530-017-1592-0

Novoa A, Shackleton R, Canavan S, Cybèle C, Davies SJ, Dehnen-Schmutz K, Fried J, Gaertner M, Geerts S, Griffiths CL, Kaplan H, Kumschick S, Le Maitre DC, Measey GJ, Nunes AL, Richardson DM, Robinson TB, Touza J, Wilson JRU (2018) A framework for engaging stakeholders on the management of alien species. *Journal of Environmental Management* 205: 286–297, https://doi.org/10.1016/j.jenvman.2017.09.059

Nummi P (2001) Alien species in Finland. The Finnish Environment 466. Ministry of the Environment, Helsinki, Finland, 40 pp

Oele D, Wagner K, Mikulyuk A, Seeley-Schreck C, Hauxwell JA (2015) Effecting compliance with invasive species regulations through outreach and education of live plant retailers. *Biological Invasions* 17: 2707–2716, https://doi.org/10.1007/s10530-015-0907-2

Piria M, Copp GH, Dick JTA, Duplić A, Groom Q, Jelić D, Lucy FE, Roy HE, Sarat E, Simonović P, Tomljanović T, Tricarico E, Weinlander M, Adámek Z, Bedolfe S, Coughlan NE, Davis E, Dobrzycka-Krahel A, Grgić Z, Kırankaya SG, Güler Ekmekçi F, Lajtner J, Lukas JAY, Koutsikos N, Mennen GJ, Mitić B, Pastorino P, Ruokonen TJ, Skóra ME, Smith ERC, Šprem N, Tarkan AS, Treer T, Vardakas L, Vehanen T, Vilizzi L, Zanella D, Caffrey JM (2017) Tackling invasive alien species in Europe II: threats and opportunities until 2020. *Management of Biological Invasions* 8: 273–286, https://doi.org/10.3391/mbi.2017.8.3.02

Rutenfrans AHM (2018) Pilotlessen Invasieve exoten in de klas; een evaluatie van lessen, docentenhandleiding en LINVEXO. Beleef & Weet, Nijmegen [in Dutch]. https://beleefenweet.nl/wp-content/uploads/2019/07/Eindrapport_2017_Feb_Pilotlessen-Invasieve-exoten-in-de-klas.pdf (accessed 24 November 2019)

Rutenfrans AHM, Odé B, De Jong G, Van der Loop JMM, Leuven RSEW (2018) Burgerparticipatie bij bestrijding reuzenberenklauw en reuzenbalsemien. Beleef & Weet,

Nijmegen [in Dutch]. https://beleefenweet.nl/wp-content/uploads/2019/07/Eindrapport_2018_Nov_Burgerparticipatie-bij-bestrijding-invasieve-exoten.pdf (accessed 24 November 2019)

Shackleton RT, Richardson DM, Shackleton CM, Bennett B, Crowley SL, Dehnen-Schmutz K, Estévez RA, Fischer A, Kueffer C, Kull CA, Marchante E, Novoa A, Potgieter LJ, Vaas J, Vazo AS, Larson BMH (2019) Explaining people's perceptions of invasive alien species: A conceptual framework. *Journal of Environmental Management* 229: 10–26, https://doi.org/10.1016/j.jenvman.2018.04.045

Smith GA (2013) Place-based education: practice and impacts. In: Stevenson RB, Brody M, Dillon J, Wals AEJ (eds), International Handbook of Research on Environmental Education. Routledge, New York, pp 213–220

Stapp WB (1969) The concept of environmental education. *Journal of Environmental Education* 1: 30–31, https://doi.org/10.1080/00139254.1969.10801479

Van Kleef H, Van der Velde G, Leuven RSEW, Esselink H (2008) Pumpkinseed sunfish (*Lepomis gibbosus*) invasions facilitated by introductions and nature management strongly reduce macroinvertebrate abundance in isolated water bodies. *Biological Invasions* 10: 1481–1490, https://doi.org/10.1007/s10530-008-9220-7

Vanderhoeven S, Piqueray J, Halford M, Nulens G, Vincke J, Mahy G (2011) Perception and understanding of invasive alien species issues by nature conservation and horticulture professionals in Belgium. *Environmental Management* 47: 425–442, https://doi.org/10.1007/s00267-011-9621-8

Verbrugge LNH, van den Born RJG, Leuven RSEW, van Valkenburg JLCH (2014) Evaluating stakeholder awareness and involvement in risk prevention of aquatic invasive plant species by a national code of conduct. *Aquatic Invasions* 9: 369–381, https://doi.org/10.3391/ai.2014.9.3.11

Verbrugge LNH, Leuven RSEW, Zwart HAE (2016) Metaphors in invasion biology: Implications for risk assessment and management of non-native species. *Ethics, Policy and Environment* 19: 273–284, https://doi.org/10.1080/21550085.2016.1226234

Wals AEJ, Brody M, Dillon J, Stevenson RB (2014) Convergence between science and environmental education. *Science* 344: 583–584, https://doi.org/10.1126/science.1250515

Wittenberg R, Cock MJW (eds) (2001) Invasive alien species: A toolkit of best prevention and management practices. CAB International, Wallingford, 228 pp, https://doi.org/10.1079/9780851995694.0000

Wu JS, Lee JJ (2015) Climate change games as tools for education and engagement. *Nature Climate Change* 5: 413–418, https://doi.org/10.1038/nclimate2566

Supplementary material

The following supplementary material is available for this article:

Appendix 1. Novel tools and best practices for education about invasive alien species.