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RESEARCH ARTICLE

'Visual Learning – Agricultural Plants of the Riverina' – A New Application for Helping Veterinary Students Recognise Poisonous Plants

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Abstract

Students studying either animal or veterinary science at Charles Sturt University are required to be competent in recognising a range of plants that are potentially poisonous to domestic grazing animals. In 2013 these students used a newly developed application '*Visual Learning – Agricultural Plants of the Riverina*' (VL-APR) for their poisonous plant recognition training. VL-APR has two main advantages over poisonous plant books or other computer-based applications. Firstly, an average of nine images per species is available, so a range of growth stages and variation in structure is shown. Secondly, multiple interactive quizzes and tests are available so students are actively engaged in the learning process. At the start of session the animal and veterinary science students obtained an average class mark (for recognition of 40 species) of 11.9%, with a wide range of individual student marks (0.0 to 40.0%). A class of first year agricultural science students was also tested and scored a similar average of 14%. About 70% of these students reported a rural upbringing (i.e. lived on farms), but apparently had little knowledge of common poisonous plants. After using VL-APR for eight weeks the animal and veterinary science students were re-tested, with an average class result of 93.0% (individual student range 45 to 100%). VL-APR would appear to be an effective resource for students to learn poisonous plant recognition at their own pace. In 2013 VL-APR was used as a standalone learning tool, but in future will be integrated with use of living plant material.

Keywords: education, identification, recognition, toxicology, toxic plants, poisonous plants, active learning, visual learning

Introduction

At Charles Sturt University (CSU), students in the Bachelor of Animal Science and the Bachelor of Veterinary Biology/Bachelor of Veterinary Science are required to be able to recognise a range of potentially poisonous plants from the south-eastern Australian region, while also learning the active chemical component and clinical signs associated with poisoning. In this paper 'recognition' means the ability to recall the name of a species almost instantaneously based on an overall assessment of a species' features. 'Identification' means the step-wise determination of a species name by using a key or similar tool. In the field, recognition is far more useful than identification, which requires the use of books or similar tools to identify a species.

Students now live in a 'smartphone' world, with the ability to share and receive data at most locations, at any time. Thus, in terms of plant recognition or identification, apps such as 'Leafsnap' and 'MobileFlora' might someday mean students and practitioners will need a reduced ability to recognise or identify plant species. With this type of application an iPhone, iPad or similar is used to take a photograph of a leaf (Leafsnap) or flower (MobileFlora), the image is uploaded to a central server where a complex array of computations compare the image against images in the database, with a listing of possible identifications quickly returned to the device. The use of the morphometric methods that underlie this type of technology for plant identification have recently been reviewed (Cope *et al*. 2012). One of the key problems faced by these methods is the variability, or lack thereof, of the taxa. As many potentially poisonous plants (e.g. Table 1) have very similar leaves (e.g. Poaceae) and/or very small flowers (e.g. Poaceae, Chenopodiaceae) applications like Leafsnap or MobileFlora will have difficulty distinguishing between these plants even if they were included in their databases, which they are currently not. For these and other reasons poisonous plant recognition is still a valuable skill.

Given the importance of poisonous plants to animal health many approaches have been used to make information on these species available to students and practitioners (Burrows 1982), including books and multimedia/computer-based approaches (Cornell *et al*. 1995, Poppenga & Spoo 2002, Els & Mostert 2004, Pelzer & Wiese 2005). Various ways of teaching poisonous plant recognition are possible (Burrows 1982), such as using herbarium specimens, live plant materials in laboratory sessions, student prepared herbaria, poisonous plant flash cards for the iPhone, excursions and poisonous plant gardens (Brownie *et al*. 1989). In this regard, see the web pages for the Poisonous or Toxic Plant Gardens at the University of Illinois and the University of California Davis. In this paper we describe the use of an interactive, computer-based application for learning to recognise poisonous plants.

Description of the program *Visual Learning – Agricultural Plants of the Riverina* (VL-APR)

'*Visual Learning – Agricultural Plants of the Riverina*' (VL-APR) is a member of the Visual Learning family of programs produced by Metis LLC (see http://metisllc.com/). Programs in this family are designed based on principles of cognitive psychology to increase comprehension of complex subjects through visual learning. Gaining expertise in a field is often associated with extensive amounts of experience in working with the visual objects that characterise that field. For instance, plant taxonomists can easily recognise species at a glance, without recourse to identification aids. They are able to do this because they have learned, through extensive experience, to efficiently utilise a part of their brain that novices use inefficiently (Bukach *et al*. 2006). Use of this area, the Fusiform Face Area, is associated not only with rapid recognition, but also with the ability to utilise non-traditional, configural or holistic characters in making identifications. Traditional characters are things like the length of the ligule in the grass family, or whether the leaves are opposite or alternate. Configural characteristics have to do with the relationships between parts. The length of the ligule relative to the diameter of the stem, and the length of the petiole relative to the length of the blade are configural characters. When we speak of holistic characters we are referring to the overall appearance of the plant, or of some plant part. When taxonomists

Table 1 The 40 species of poisonous plants that the students were required to recognise.

Species	Family	Common name	Number of alternative common names	Toxic agent
**Lotus corniculatus*	Fabaceae	—	—	Cyanogenic glycosides
Chloris truncata	Poaceae	windmill grass	3	Cyanogenic glycosides
Cynodon dactylon	Poaceae	couch grass	9	Cyanogenic glycosides
**Holcus lanatus*	Poaceae	Yorkshire fog	3	Cyanogenic glycosides
**Paspalum dilatatum*	Poaceae	paspalum	3	Cyanogenic glycosides
**Sorghum halepense*	Poaceae	Johnson grass	2	Cyanogenic glycosides
**Amaranthus hybridus*	Amaranthaceae	slim amaranth	1	Nitrate/nitrite + unidentified toxin
**Arctotheca calendula*	Asteraceae	capeweed	1	Nitrate/nitrite
**Silybum marianum*	Asteraceae	variegated thistle	7	Nitrate/nitrite
**Capsella bursa-pastoris*	Brassicaceae	shepherd's purse	5	Nitrate/nitrite
**Sisymbrium officinale*	Brassicaceae	Indian hedge mustard	10	Nitrate/nitrite + glucosinolates
**Chenopodium album*	Chenopodiaceae	fat-hen	2	Nitrate/nitrite + oxalates
**Echinochloa crus-galli*	Poaceae	barnyard grass	8	Nitrate/nitrite
**Marrubium vulgare*	Lamiaceae	horehound	6	Nitrate/nitrite
Chenopodium pumilio	Chenopodiaceae	small crumbweed	3	Oxalates
**Oxalis pes-caprae*	Oxalidaceae	soursob	7	Oxalates
Oxalis perennans	Oxalidaceae	—	—	Oxalates
**Acetosella vulgaris*	Polygonaceae	sheep sorrel	5	Oxalates
**Rumex crispus*	Polygonaceae	curled dock	0	Oxalates + nitrate/nitrite
Portulaca oleracea	Portulacaceae	common pigweed	2	Oxalates
**Pennisetum clandestinum*	Poaceae	kikuyu grass	0	Oxalates + nitrate/nitrite
**Amsinckia intermedia*	Boraginaceae	common fiddleneck	3	Pyrrolizidine alkaloids
**Echium plantagineum*	Boraginaceae	Paterson's curse	4	Pyrrolizidine alkaloids
**Heliotropium europaeum*	Boraginaceae	common heliotrope	6	Pyrrolizidine alkaloids
**Xanthium spinosum*	Asteraceae	Bathurst burr	3	Diperpenoid (kaurene) glycosides

Table 1 *(Continued)*

**Convolvulus arvensis*	Convolvulaceae	bindweed	5	Tropane alkaloids
**Citrullus lanatus*	Cucurbitaceae	camel melon	5	Cucurbitacins
**Cucumis myriocarpus*	Cucurbitaceae	paddy melon	2	Cucurbitacins
**Hypericum perforatum*	Hypericaceae/ Clusiaceae	St. John's wort	4	Hypericin
**Panicum capillare*	Poaceae	witchgrass	1	Steroidal or lithogenic saponins
**Phalaris aquatica*	Poaceae	phalaris	2	Indole alkaloids
**Datura ferox*	Solanaceae	fierce thornapple	3	Tropane alkaloids
**Papaver hybridum*	Papaveraceae	rough poppy	1	Isoquinoline alkaloids
**Centaurea solstitialis*	Asteraceae	St. Barnaby's thistle	3	Sesquiterpene lactones and tyramine proposed
**Hypochaeris radicata*	Asteraceae	flatweed	4	Unknown toxin
**Biserrula pelecinus*	Fabaceae	—	—	Unknown toxin
**Stachys arvensis*	Lamiaceae	stagger-weed	4	Unknown toxin but suspected to be unsaturated fatty acid
**Malva parviflora*	Malvaceae	small-flowered mallow	4	Unknown toxin + nitrate/nitrite
**Polygonum aviculare*	Polygonaceae	wireweed	2	Unknown toxin + nitrate/nitrite
Tribulus terrestris	Zygophyllaceae	cat-head	9	Nitrate/nitrite + steroidal or lithogenic saponins and unidentified neurotoxin

Note: An asterisk (*) at the start of the species name indicates that the species is naturalised or is sown. ‘Common name’ is the common name recommended by Cunningham *et al*. (1981). The number of alternative common names given by Cunningham *et al*. (1981) is provided to show how variable common names can be for these mostly naturalised (‘weed’) species.

say a plant just ‘looks different’, they are referring to a holistic, or Gestalt, characteristic of the plant.

It is a peculiarity of our visual system that novices only have access to traditional characters, while experts can see both traditional, configural, and holistic characters. Experts thus have a richer store of experience on which to draw when making identifications. Programs like VL-APR are designed to give users extensive experience with organism identification so that they become visual experts. This experience is delivered through a series of active-learning quizzes and tests to ensure that students get maximum value from the use of the program (Schroeder & Spannagel 2006).

Currently VL-APR includes images and data for 153 plant species of the Riverina region [southern inland New South Wales (NSW)], a large area of diversified agricultural production in Australia. The species included are crops, native and sown pasture species, weeds of both crops and pastures and remnant trees and shrubs. Currently the program has 1413 images, an average of about nine images per species. Thus for each species there are images of whole crops or communities, individual plants, vegetative plants, plus close ups of inflorescences, flowers and fruits. For this project a subset of 40 species known to be potentially poisonous to domestic stock were selected (Table 1). For these 40 species there were 403 images, an average of about 10 images per species. Of these species, 24 were annuals or biennials and 16 were perennial herbs. About 15% were native to the Riverina (or at least Australia), while the remainder were naturalised species ('weeds'). One definition of a weed is 'a plant perceived to be in the wrong place' (Beentje 2010). By this definition several of the native species (e.g. small crumbweed) would probably be considered 'weeds' by farmers, while some of the potentially poisonous plants (e.g. kikuyu grass and phalaris) are actively established by farmers but can be poisonous under specific circumstances.

The main screen for VL-APR has eight buttons (Figure 1), arranged into upper and lower groups of four. The upper buttons are used to select species to study, while the lower buttons select the way that the species are studied. The program also allows for the creation of subsets of species that can be saved for future study (File-Save/Load Taxa set) and includes a scripting function, available through a free add-on, through which customised student study sessions can be created (File-Load Script). By creating and saving subset files the instructor can assign weekly study sets based on required species such as 'week 1 species', 'week 2 species', etc. Sets of plants with specific poisonous compounds (oxalates, cyanogenic glycosides, etc.) or a specific set of plant families (e.g. Fabaceae, Poaceae, etc.) can also be saved. Students having difficulties with certain species can quickly create and share their own study sets. At all stages of using the application students can select whether they want to work with common or scientific names.

Once a group of plants has been loaded from a study set or selected through 'Search', 'Group Selection', 'Taxa Selection' or 'Load Saved Taxa Set' (Figure 1) students have two main options to hone their recognition skills. Firstly, students should use 'Study Plants' to display and scroll through the images of the selected species, so they can assess the range

Figure 1 The main screen for *Visual Learning – Agricultural Plants of the Riverina* (VL-APR). The upper four buttons are used for selecting taxa, while the lower four are used for studying and learning the selected taxa.

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of variation and see detailed images of characters of recognition importance, such as leaf shape and arrangement, flowers and fruits. Secondly, after becoming familiar with the species, students can ‘Take a Quiz’ (feedback is given after each image/answer) or ‘Take a Test’ (feedback is given only at the end of the set of images). In these modes the program allows selection between several active-learning routines to help students develop their recognition skills. In the most demanding of these routines the program selects an image at random from the pool of active images, the image is then displayed on-screen for a short period (selectable between 0.1–4.0 seconds), the image is cleared from the screen, then the student enters the answer in a response box. Spelling sensitivity is selectable (in 10% steps, from 100 to 60%) which is helpful in the early learning stages. As noted, in a Quiz feedback is given after each answer. If an incorrect response is given a student can select to see the correct answer before repeating the question, repeat without seeing the answer, or skip to the next question. The Quiz and Test modes also have routines where two images are displayed simultaneously and the user needs to indicate if they are the same or different taxa. A mode where an image is displayed, followed by a name, with the user needing to indicate if the name and image correlate is also available. VL-APR is available at no charge for PC and Mac computers from the Metis LLC website (http://metisllc.com/).

Experimental design

Third year students in the Bachelor of Veterinary Biology/Bachelor of Veterinary Science and final year students in the Bachelor of Animal Science were tested on their ability to recognise 40 potentially poisonous plants (Table 1) commonly encountered in the Riverina region of NSW. As noted, the Wagga Wagga campus of CSU is situated in a large region of diversified agricultural production. Thus, these 40 species relate to potential poisoning of farm animals and do not include indoor or garden plants that may poison companion animals. The students were shown a PowerPoint presentation of the 40 species in their first class of the relevant subject in early March. The PowerPoint slides all featured at least two images of each species, a general habit image and a close up of a key feature for recognition, e.g. often the flower and/or fruit (Figure 2). All of the images used in the pre-test were also present in VL-APR. These PowerPoint slides were considered the best practical way to ascertain if students could recognise a species, as the slides usually had greater information content than a single live or herbarium specimen, especially when time of year is factored in (see later). The use of PowerPoint slides also meant that the whole of a large class was able to be tested at the same time. A class of first year Agricultural Science students, in their first week at university (early March), was also tested to obtain a wider view of student plant recognition skills. At this initial stage only common names were required as answers, as previous testing had shown that these students usually had no knowledge of scientific names of plant species. One mark was given for a correct full common name, and a half mark for a partial common name, e.g. ‘poppy’ rather than ‘rough poppy’. The students were also surveyed to find out if they had a rural or urban upbringing.

Straight after the initial test the animal and veterinary science students were provided with access to VL-APR so they could install it on their own computers and work on the material at their own pace. Students were shown how to use the main features of VL-APR in class. A comprehensive illustrated tutorial, list of help topics and list of keyboard shortcuts is also available within the program. In addition, the CSU Virtual Herbarium features a range of leaf and flower morphology interactive tutorials and tests if students wish to revise vegetative and reproductive morphology relevant to species recognition (Burrows 2008, 2010a, 2010b). For 2013 there were no classes with live or pressed specimens, e.g. herbarium specimens, plants in pots in glasshouses, or excursions, i.e. VL-APR was the only form of instruction students received for plant recognition. Related to this is that poisonous plant recognition is a component of an autumn subject that commences at the

Figure 2 An example of one of the PowerPoint slides used in both the pre-test and summative test, in this case for *Oxalis pes-caprae* (soursob). Note that the slide provides a good range of information about the species. In terms of providing students with live specimens there are various problems. This herbaceous perennial is only in leaf for a few months each year, it flowers for an even shorter period, the flowers do not open on dull days, uprooted plants rapidly wilt and leaves of dried specimens quickly turn a dull brown.

end of summer, in a region with a Mediterranean-type climate. In 2012/2013 the five months from December to April (summer to autumn) produced drought-like conditions (111 mm rainfall, compared to a long-term average of 214 mm), during which all annuals died and most perennial herbs died back to their rootstocks, bulbs or similar structures. Thus it was difficult to provide live specimens. The use of VL-APR provided a way for students to practice their recognition skills during these unfavourable climatic conditions.

Eight weeks later the animal and veterinary science students, but not the agriculture students, were given a summative test (worth 30% of subject's marks), again using a PowerPoint presentation. Images for 24 of the taxa in this test were images the students had never seen before. These images were taken at different times of the year and were of different populations of plants than those used in VL-APR, i.e. they were completely new, not just a slightly different angle or magnification of those used in VL-APR. They provided an independent test of the students' knowledge of the taxa. The images for the other 16 taxa in the test were taken from VL-APR, as additional images could not be sourced during the drought. The students had seen these images in both the pre-test, and while using VL-APR. Given the multitude of common names (Table 1, an average of five common names per species) and the confusion that this can create when trying to communicate about a particular species, the learning of scientific names was emphasised for this class. For the purposes of this research, either a correct scientific or full common name counted one mark (full credit), as the emphasis was on whether the students could recognise the species. For subject grading purposes a correct scientific name was worth one mark, while if only a correct common name was provided it was worth half a mark.

At the end of the exam paper we included an open-ended response area where students could indicate what they liked about VL-APR, the process of learning to recognise poisonous plants in general, and what aspects of the program could be improved.

Papers were assessed from both student and species perspectives, i.e. the score individual students obtained, class averages, which species were correctly identified, and which species were commonly misidentified. IBM SPSS Statistics version 19 was used to calculate means and perform *t*-tests. Marks for 91 of the animal and veterinary science students could be paired between the pre-test and summative test. Twelve other students did not take the pre-test, so their data was excluded from the analysis.

The research had CSU Human Ethics Committee approval and Institutional Review Board approval from University of North Carolina at Greensboro (UNCG).

Results

Pre-test performance

For the initial test the first year agricultural science students ($n = 68$) obtained an average of 14.2% (standard deviation [SD] ± 7.9), with individual student marks ranging from 1.3 to 32.5%. The majority (80%) of these students indicated that they had a rural upbringing, i.e. lived on a farm or similar, and 20% had an urban upbringing.

The animal and veterinary science students ($n = 91$) obtained an average mark of 8.5% (SD ± 6.7; median (Med) = 6.3%) for the 16 taxa where images from VL-APR were used in the summative test. Student marks ranged from zero to 31.3%. For the set of 24 taxa where new images were used in the summative test, the average mark on the pre-test was 14.2% (SD ± 11.1; Med = 12.5%), with marks ranging from zero to 56.3%. A paired sample *t*-test showed a significant difference between these two sets of taxa ($p < 0.001$), with the 24 taxa where new images were used on the summative test being slightly easier to identify than the 16 taxa where repeated images were used. The overall mean for both sets was 11.9% (SD ± 8.5; Med = 10.0%), with a range of zero to 40%. Like the agriculture science students, most of the veterinary students indicated that they had had a rural upbringing (59%), while 41% had an urban upbringing.

An independent-means *t*-test for equality of means without equal variances was used to compare the performance of the agriculture and veterinary students on the pre-test. There was no significant difference in these means ($p = 0.090$).

Overall, approximately 75% of the answer spaces were left blank by both sets of students. The species most frequently correctly recognised were: *Echium plantagineum* (Paterson's curse) (71.9%), *Arctotheca calendula* (capeweed) (39.8%), *Xanthium spinosum* (Bathurst burr) (34.3%), *Silybum marianum* (variegated thistle) (34.0%), *Citrullus lanatus* (camel melon) (34.0%) and *Tribulus terrestris* (cat-head) (30.2%). Four of the 40 species [*Chenopodium pumilio* (small crumbweed), *Convolvulus arvensis* (bindweed), *Biserrula pelecinus*, *Stachys arvensis* (stagger-weed)] were unknown by any students. *Oxalis pes-caprae* (Figure 1) and *Oxalis perennans* had the highest percentage of incorrect names recorded, at 31% and 24%, respectively. Almost all the incorrect names for these two species were 'clover' or a similar variation.

Summative exam performance

The final summative exam was only given to the animal and veterinary science students ($n = 91$). The average score on the 16 images from VL-APR was 96.8% (SD ± 8.3; Med = 100%), with student marks ranging from 50 to 100%. For the 24 images that the students had never seen before the average score was 90.5% (SD ± 12.0; Med = 91.7%), with marks ranging from 25 to 100%. Marks on these two sets of plants were significantly different ($p < 0.001$), with the 16 taxa with images taken from VL-APR being slightly easier to identify than the 24 taxa for which new images were presented. The overall mean for all questions was 93.0% (SD ± 9.8; Med = 95%), with a range of 45 to 100%.

Paired sample *t*-tests between the pre-test and summative test for both the 16 and the 24 taxa sets were statistically significant ($p < 0.001$).

The following species were those most commonly incorrectly recognised on the summative test: *Cynodon dactylon* (couch) (39%) was most commonly misidentified as *Polygonum aviculare* (wireweed), *Rumex crispus* (curled dock) (31%) as *Acetosella vulgaris* (sheep sorrel), *Polygonum aviculare* (wireweed) (31%) as a wide range of species but mostly as *Cynodon dactylon* (couch), *Chenopodium album* (fat-hen) (19%) as *Amaranthus hybridus* (slim amaranth), and *Pennisetum clandestinum* (kikuyu) (18%) as *Cynodon dactylon* (couch).

Of the four species that were unknown by any students in the pre-test *Chenopodium pumilio* (small crumbweed) was misidentified by 13% of students on the summative test, while the other three species were misidentified by less than 7% of students. The two *Oxalis* species were misidentified by less than 4% of students, with no students indicating that they were clover (*Trifolium*) species.

The feedback from the survey is described and analysed in the Discussion section.

Discussion

Teaching plant identification

There are three main ways in which plant identification is commonly taught. The first method involves focusing on diagnostic characters. The instructor teaches students to search for and recognise these features. A student is taught to evaluate an unknown in the following way. 'I've never seen this plant before, but I can tell that it is in the Lamiaceae as it has a zygomorphic corolla, gynobasic style, etc.' This method depends on a clear understanding and memory of the technical terms. The second method consists of teaching students to use a taxonomic key, and giving them extensive practice in keying out unknown plants. In using keys students are forced to be observant, and must learn the technical terms upon which the keys depend. Both of these approaches depend on a student's ability to learn the technical and often arcane terminology of plant identification. A third way involves a form of field recognition where a name is associated with a particular specimen without a deep understanding of botanical features or terminology. This last method is most often used in courses with a strong field component.

Teaching methods in horticulture and agriculture courses are often a hybrid among several of the previously described methods. In all cases the students are expected to develop sight-recognition of each crop or horticultural variety (Kahtz 2000, Anderson & Walker 2003).

Limitations of current teaching methods

There are several shortcomings with current methods of teaching plant identification. The first and most serious of these are the problems associated with learning the enormous technical vocabulary. The number of terms is truly staggering (Simpson 2010, pp 451–508). Even the best students have difficulty mastering this terminology. All of the methods also depend on the students being able to see living representative specimens. While seeing living plants is an excellent way of teaching, the method has shortcomings. The specimens must either be made available as cut specimens in the laboratory, or as living specimen in the field. Cut specimens require a great amount to time to collect, require extensive laboratory space for display, and must be replaced frequently. Plant identification tests

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based on living specimens can also be laborious to set up and grade (Pokorny 1988). Outdoor laboratories are susceptible to inclement weather, can only be conducted during daylight hours, and are time consuming (Kahtz 2000, Anderson & Walker 2003).

No matter how the plants are seen, current methods only allow the students to see a limited amount of taxonomic variability. For instance, in studying the daisy family (Asteraceae) the students may be exposed to only three or four genera out of approximately 1600 in the family. In addition, a single plant can vary considerably over just a few months, e.g. an annual species developing from a seedling, through the vegetative stage to flowering, then fruiting, then senescing. For field-based applications (e.g. vegetation surveys, weed spraying assessments, species potentially involved in animal poisonings) recognition at all phases is required. None of the current methods have a mechanism for dealing with this amount of variation. Increasing exposure to variability is important because concepts capture information about variability as well as information about the prototype of the conceptual category (Wisniewski 2002).

Previous use of computers in teaching plant identification

Some prior attempts have been made to incorporate computerised methods into plant identification classes. These have included the use of stand-alone (Pokorny 1988, Sabota *et al*. 1995, Kahtz 2000) and web-based tools (Anderson & Walker 2003). The stand-alone tools were used both for teaching (Sabota *et al*. 1995, Kahtz 2000) and assessment purposes (Pokorny 1988, Sabota *et al*. 1995, Kahtz 2000). Of the three studies that used computer-based instruction, none found a significant difference in comprehension between students trained on the computer and those trained with traditional methods (Pokorny 1988, Sabota *et al*. 1995, Kahtz 2000).

Pre-test

The pre-test indicated that the animal and veterinary science students had a low ability (average 11.9%) to recognise potentially poisonous plants from agricultural systems in the Riverina, even when only required to use common names. First year agriculture students had a similar low ability (average 14.2%). There was no significant difference between these averages. Across the two groups about 75% of the answer spaces were left blank, which indicates that the background necessary to make even an educated guess was not present. As could be expected, a wide range in the performance of individual students was recorded (0–40%). Interestingly, about 60% of the animal and veterinary science students and 80% of the agriculture students indicated that they had a rural upbringing, i.e. had grown up on farms. Similar results have been recorded regarding the ability of agriculture students to recognise a wide range of agriculturally important plants, not just poisonous plants (Burrows 2012). An initial recognition capacity of around 30% was recorded in a test that included several species that are sown on a large scale, such as phalaris, barley, lupin, subclover, lucerne, and canola (Burrows 2012). While a high proportion of students enrolling in animal, veterinary and agricultural science degrees at CSU have a rural upbringing, they generally appear to have a form of 'plant blindness' (Wandersee & Schussler 1999) and have acquired few plant names while on the farm. Certainly, if animal and veterinary science graduates are expected to be able to recognise poisonous plants, then training in this area will need to be provided.

Of the six initially best known species the top two [*Echium plantagineum* (Paterson's curse), *Arctotheca calendula* (capeweed)] are visible at a landscape level when flowering, with purple and yellow paddocks, respectively, a common sight in spring in the Riverina. Three of the next four species [*Xanthium spinosum* (Bathurst burr), *Silybum marianum* (variegated thistle), *Tribulus terrestris* (cat-head)] have sharp projections of various types and thus were probably encountered by painful experiential learning, while *Citrullus lanatus* (camel melon) has a highly distinctive fruit similar to small watermelons.

Summative test

After using VL-APR for eight weeks the animal and veterinary science students were re-tested, with a class average of 93.0% and a median of 95%. This represents an overall improvement of 81.1% over the pre-test results. It would appear that VL-APR is an effective tool or application for allowing students to independently learn poisonous plant recognition. Its use is one way to overcome 'plant blindness'.

Because the final summative test included both new images that the students had never seen ($n = 24$) and images that the students had seen in VL-APR ($n = 16$), we performed independent analyses of student performance on these sets of taxa. These analyses only apply to the animal and veterinary science students, because they were the only ones to take the summative test. A comparison of student marks on the pre-test showed that the 16 taxa for which repeat images were used on the summative test were statistically significantly harder on the pre-test ($p < 0.001$). When the same analysis was run on the summative test this disadvantage had disappeared. These 16 taxa where repeat images were shown were now statistically significantly easier ($p < 0.001$). The amount of improvement difference was 88.3% (96.8–8.5%) for the 16 repeated images, and 76.3% (90.5–14.2%) for the 24 new images. These results show that VL-APR promotes significant taxon learning and does not teach simple image matching. If an image matching strategy were being used, student marks on new images would have been much lower than the 76.3% improvement that we recorded. The students would not have been able to reliably identify the taxa from new images. However, these results also emphasise the importance of using new images in summative tests in order to accurately assess the extent to which taxon, not image, learning is taking place.

Evaluation of which species were commonly recognised incorrectly can be used to help the students in subsequent years. Three of these species had narrow prostrate stems (couch, kikuyu, wireweed) and the differences between these species can be emphasised to the students, who can then be encouraged to create their own study set for these species.

In the feedback section, the most common responses were that the students appreciated the quality and variety of the images at different stages of development, rather than just a single image per species, with the interactivity of the quizzes and tests also frequently mentioned.

In terms of improvement to the program many of the suggestions made by the students were already available (e.g. ability to save taxa selections, make the quizzes shorter, get immediate answers, allow some flexibility in spelling). This indicated the need to provide better training sessions on how to use the program as some students were apparently not making use of the help and tutorial files where this information was presented. As VL-APR only addresses plant recognition, with the toxic properties needing to be learnt outside of the program, several students suggested that toxins should be integrated into the program. This would certainly be worthwhile but would entail a large change to the programming. Several students indicated that while the program was useful it should be integrated with some access to live plants, either through having live plants in a laboratory, doing a plant collection, giving locations of species on campus and/or having organised excursions. Until this year poisonous plant identification/recognition was primarily taught through a plant collection assignment. Difficulties with this approach included: annual variability in species available depending on rainfall, the need to include flowering specimens and the time taken to collect, dry and present the plant specimens.

Conclusions

VL-APR was designed to be a support to hands-on practicals or similar, i.e. a way that students could practice at their own pace what they have seen in class. While the positive results from this standalone use of VL-APR can be considered a solid endorsement of the program, a combination of living specimens (where possible) and VL-APR is likely to result in even better learning outcomes. Beginning in 2014 students will have access to VL-APR to assist in their recognition of species, but will also be required to present a herbarium collection of specific toxic plants. This will be a means of assessing if the recognition skills developed using VL-APR are transferrable to the field.

There can be a concern as to how image-based plant recognition applications (books or computers) transfer to the real world. One of the authors of this paper (G.E.B.) has developed a range of interactive, online applications for learning plant structure (see the CSU Virtual Herbarium http://www.csu.edu.au/herbarium). Distance education students from several degrees are required to work through this material before coming to residential schools, where they are tested on these concepts using live plants. Students usually obtain better than 80% on these tests, which shows a good transfer of knowledge from the virtual to the real world.

While a plethora of material is available describing and listing poisonous or toxic plants of relevance to veterinarians, few resources are available to help students independently develop their recognition skills. We consider VL-APR a useful contribution to this area as it is embedded within visual learning theory and features quality images combined with various types of interactive tests and quizzes. VL-APR includes poisonous plants other than those listed in Table 1 and is also easily expanded. We would welcome enquiries to adapt it to other regions.

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