COMMENTARY

Entomology and the Art of Creativity

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We don't know Sir Ken Robinson personally, so we could not invite him to be a co-author, but his monologue on TED TV (http://www.ted.com/talks/lang/eng/ken_robinson_says_schools_kill_creativity.html) has been watched by over 6.0 million people, and it was the key inspiration to this article. The main take-home messages from Robinson's monologue are that 1) nobody can predict the future even five years from now; 2) creativity should be considered one of the most valuable human assets and the backbone of education systems around the world; and 3) it is important to be willing to take risks, and many of us lose that willingness as we grow older. Although his monologue speaks broadly about education, we argue that it has tremendous relevance to an urgently needed discussion about how we as teachers can be more creative and make entomology an essential and more relevant discipline for future students.

The potential of entomology. Compared to most other natural sciences, entomology has a huge advantage—kids see insects on a daily basis, and most kids are inherently attracted to them. There are plenty of excellent resources available to entice interest in science through exercises and projects involving insects. Thus, if introduced at an early age, it is likely that these kids will later understand and appreciate the value of entomology as a discipline. There are even examples of school kids publishing entomology research in one of the most respected science journals (Blackawton et al. 2010), showing how relevant entomology can be in early childhood education. Insects continue to dazzle and inspire us with their extraordinary evolutionary resilience, beauty, and ecological adaptations.

Despite the considerable potential of entomology, most U.S. universities no longer have independent entomology departments, and it is harder and harder to recruit students (especially graduate students) to entomology. In countries like Brazil, most federal and/or agricultural universities still have entomology departments, and they can successfully recruit students at all levels. But in both countries, it appears that in our "sales pitch" to students, we typically highlight four areas in which entomology is important (and therefore a valid and meaningful career path):

1) Despite centuries of research and practical applications, many insects are part of our daily livelihood as disease vectors and pests, and more research into their ecology and control is needed.
2) Insects continue to be essential for production of many food products as pollinators and natural enemies, and we need research into their economic and ecological importance.
3) As bio-indicators and as part of conservation programs, we need more knowledge about insects and their roles in food webs.
4) Insects are excellent model organisms for molecular and physiological research—think of the fact that four Nobel prizes in medicine were given to scientists working with fruit flies (*Drosophila melanogaster*) as a model organism!

All of these areas of research are clearly important and will undoubtedly continue to constitute the educational backbone for most entomology students. However, we argue that entomology can be made relevant to an even wider audience of students by changing the structure and content of traditional entomology courses by teaching entomology in the context of emerging global trends. Secondly, we argue that there are ample opportunities for using creative teaching approaches in entomology classes, and thereby increasing student interest in entomology, and a few will be briefly described. In this article, we intend to address the fundamental question: On a broad scale, are we as entomology teachers preparing our students appropriately for challenges they will face after graduation? Continuously throughout this article, we will refer to Robinson's monologue, and for the sake of argument, we argue that the answer to the question addressed is "no."

Entomology in an ever-changing world. Let's start with a simple scenario based on the assumption that it takes about 10 years to graduate from a university with a Ph.D. in entomology (four years as an undergraduate, two years to complete a Master's degree, and four years to complete a Ph.D.). What did the world look like in 2001 (http://www.historyorb.com/events/date/2001)? In more specific terms, if you were a freshman college student in 2001, what events would influence your daily life and your decisions about what to study? The main point we intend to make is that things like Twitter, Facebook, climate change, oil resources, national security, and exploding economies in countries like Brazil, China, and India were not on students' radar as they are today. Back in 2001, there was no way anybody could have predicted the current world situation, but (as pointed out by Robinson) we as teachers were supposed to prepare students for graduation and the job market in 2011. Did those of us teaching between 2001 and 2011 seriously look at how important world events were changing the status quo, and did we adjust our class curricula accordingly so that our class materials were up to date and preparing the students for an ever-changing future and job marketplace?

Entomology and internationalization. Many may argue that applied entomology at a U.S. university and economic growth in countries like Brazil are two topics with very little in common, but the relationship is actually not that farfetched. Since 2001, companies like Syngenta, Monsanto, BASF, Pioneer, Bayer, and DuPont (all the "heavy hitters") have established tremendous business in countries like Brazil and are making fortunes in the exploding agricultural industry. Brazilian entomology students barely finish their degree before they are offered industry jobs, and there is a tremendous growth due to new funding sources in applied entomology research across a wide range of universities and research institutions.

Very similar trends are occurring in China. Between 2001 and 2011, it is unlikely that even one U.S. undergraduate advisor suggested to his or her entomology students that it would be of incredible value to study applied entomology and also get a minor in Portuguese, Hindi, or Chinese. However, large international agrochemical companies are wondering who in their research and development areas can conduct and supervise the research required to understand and set market values, as well as keeping them on the forefront of pest challenges and pest resistance issues. Such job demands require, among other skill sets, basic insect taxonomy to identify and monitor changes in pest populations, but also cultural and language experience.

Which U.S. universities are seriously developing degree programs to educate entomology students to meet the challenges and potentials in emerging economies? In Brazil or the U.S., it seems logical that universities should offer foreign language instruction as part of the undergraduate education so that entomology students would be better prepared for a job market associated with a rapidly growing agricultural sector and with increasing levels of internationalization.

"Packaging" entomology. We have already highlighted some of the traditional entomology degree programs (vector-borne diseases, ag-production, and conservation), but very important lessons can be learned from programs like forensic entomology, which in entomology departments at several U.S. universities constitutes one of the largest undergraduate programs. Clearly, the success of these programs is not due to tremendous interest in Dipteran taxonomy or maggot ecology. In fact, it is likely a fascination that has very little to do with insects and is much more driven by the "forensic" than by the "entomology." We think the important lesson to learn from the success of forensic entomology is that course names ("branding" in marketing terms) and context have to be appreciated. Creative names of entomology courses addressing meaningful topics could potentially attract many graduate and undergraduate students; for instance, "Insects and Biofuel Crops." Such a course could address at least three important areas of entomological research: 1) digestive systems, 2) pest ecology, and 3) economic modeling of pest populations.

Regarding the relevance of insect digestive systems, it is important to highlight termites and other insects, which are intensively studied due to their unique gut flora and ability to digest ligno-cellulose (Tartar et al 2009, Scharf and Boucias 2010). Few students would likely choose a course entitled "Physiology of Insect Digestive Systems," but they might be much more interested in this topic if it were presented in a modern and real-world context.

The main goal of breeders of biofuel crops is to develop large, perennial plants with high digestibility and concentration of soluble sugars in order to optimize productivity, length of harvest period, and ethanol-producing potential. The unfortunate fact is that precisely these characteristics may lead to increased susceptibility to insect pests. Consequently, it seems important to consider insect pest management and economic insect pest modeling studies of biofuel cropping systems, especially in biofuel crops without Bt events. Diminishing irrigation water and climate change may profoundly affect insect pest pressures and insect-based food webs. We need entomologists who are prepared to tackle such challenges, and that may require complementary education in plant stress physiology, meteorology, modeling. There are endless ways entomology could be combined with such disciplines and produce highly relevant careers.

Teaching entomology in 2011. The number of insect genomes fully described and publicly available is exceeding 700 and rapidly growing (http://www.genomesize.com/statistics.php?stats=insects#stats_top), and the "insect Manhattan Project" expects to produce descriptions of 5,000 insect species (Levine 2011). The combination of genetic research and computer power has revolutionized insect taxonomy, so that (for a small fortune) tools like pyrosequencing can now provide the most incredible information about insect samples and identify levels of genetic heterogeneity in ways that were not even conceivable in 2003. Despite having these incredible molecular tools at our disposal, we are still, to a wide extent, teaching insect taxonomy the old-fashioned way and demanding that students memorize vein patterns of hymenopteran insects and the tarsal formulas of beetles. Here, we are obviously simplifying things, but there is no doubt that today's insect taxonomy is very different from what it was 10 years ago. The main point here is not that insect taxonomy has become less important, but that opportunities for innovative taxonomy have exploded. Yes, there is less need for the old-fashioned taxonomist working with sample preparation, dichotomous keys, and morphological identification under a stereoscope, but the new molecular technologies allow us to ask questions we never thought possible. It is our role as teachers to demonstrate these opportunities to new generations of entomologists and let them define the future of insect taxonomy. We suspect that most entomology programs, especially at the undergraduate level, do not meet this challenge satisfactorily. Consequently, students are not seeing the incredible potential of becoming an insect taxonomist, and at the other end of the career path, companies and research institutions are not able to fill vacant positions because they cannot find qualified applicants.

In the aforementioned video, Robinson defines creativity as "developing something of value," and we argue that our role as entomology teachers should be to maximize the likelihood that our students produce valuable things. If this is set as the overall goal, then how can we develop our class curricula accordingly, when we also acknowledge that the world is unpredictable? In our view, that is one of the most profound questions we need to ask ourselves as entomology teachers, and we obviously do not claim to a have a definite answer. However, we suspect that too many entomology professors spend too little time reflecting on what sort of jobs will await their students and how their courses prepare students for those jobs.

Incredible amounts of information and insect-related databases (i.e. http://tolweb.org/tree/) are now readily available on the Internet, so that traditional memorization has become less important; a quick Google search can provide photos and definitions within milliseconds. This acknowledgement that vast amounts of entomological information is freely available on the Internet should not be considered an argument for "dumbing down" courses, but it allows teachers to demand new and more challenging outputs by our students. For example, instead of having students simply memorize the parts of the insect leg, we can now request them to find photos and literature on the Internet and compare their forms and functions. Most of the students have computers, tablets, or smartphones, and most universities have strict rules that they should not be used during exams. Why not embrace the new technology and produce exam questions that are based on students' ability to collect, compare, and discuss information—an approach that more closely approximates the way they will work after graduation, when they get a "real" job? It has been our experience that entomology students become most engaged when allowed to answer exam questions in a way that is relevant to their own career path and interests.

Despite incredible industrial and technological revolutions during the last 160 years, the world is still full of problems. Development has solved some of our problems, but it has created others, so there is a continuing need to adapt to new challenges. We as entomologists should not consider ourselves dinosaurs, but we need to be creative, embrace new technologies and challenges, and "package" them as opportunities as part of our teaching and research so that our students can play significant roles in our communities.

Finally, we are considering putting together a symposium for the 2012 national ESA meeting, in which we would like to discuss the issues addressed in this article. Ideally, we would have many different speakers providing teaching examples and thoughts about how to increase the level of creativity in entomology teaching and how to develop entomology courses that address future needs. Please contact one of us if you would be interested in presenting at such a symposium, and give us a brief description of what you have in mind.

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Gil: But, you know, uh, Rochie was a, uh, bit of a health nut. He always stuck to a balanced diet. A drink in each hand. (cricket chirping)

Gil: 'Cause the diet was...balanced. Okay, I put together a little video tribute. 'Cause it's not the first time Rochester's died on stage. (cricket chirping)

Cricket: Yo, back off. The guy's funny.

So, although perhaps in no other way remarkable, this episode of *Greg The Bunny* marks the passage of more than a half-century of rabbit entertainers dying onstage to the sounds of chirping crickets. I think that would have made Bugs Bunny very happy—or should I say "hoppy?" (cricket chirping)

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