Using a game-to-class pipeline to teach ecology

Students studying ecology are often required to master complex concepts while simultaneously learning complementary, in-depth bodies of knowledge such as taxonomy and morphology. For instance, ecology students may be expected to understand a species–area relationship while concurrently learning to identify species. However, because species identification data are a necessity for illustrating the species–area relationship, students' grasp of the greater ecological take-away message may be challenged by competing learning priorities.

We present an alternative approach for teaching ecological concepts, whereby active learning improves student performance (Handelsman *et al.* 2004; Brewer and Smith 2011; Freeman *et al.* 2014). By incorporating game play into our curriculum (Garris *et al.* 2002), we disaggregated ecological patterns from processes. Using a popular mobile video game (and pairing students to reduce accessibility issues), we engaged students and lowered traditional educational barriers (eg intimidation and/or lack of taxon-specific knowledge, both of which could inhibit students' understanding of core ecological concepts; Mayo 2009; Dorward *et al.* 2016). Our "game-to-class pipeline" approach introduces information to be built upon later through structured lecture material. As an analogy to studying ecology, once students know the rules of the game, understanding who the players are is much easier.

Notably, the game-to-class pipeline is not a substitute for learning; rather, it is an alternative or complementary strategy addressing the previously mentioned barriers for students across varied levels of experience (Sadler *et al.* 2013; Perry and Klopfer 2014). Decoupling fine-scale knowledge from complex theories reduces confusion among students being introduced to ecology. This ultimately helps students retain the "bigger picture", which is critical for application in broader biodiversity conservation (Tewksbury *et al.* 2014; Hamari *et al.* 2016).

We used Pokémon GO (Niantic, Inc; San Francisco, CA) to teach students how to assess and quantify biodiversity. Through their smartphone's camera, players navigate an augmented reality populated by different animated animals called Pokémon (Figure 1). Pokémon are heterogeneously distributed by habitat, and new Pokémon are revealed as players ascend experience levels. Because each Pokémon is identified to a species-like level, students can generate site-specific species inventories and subsequently compile a dataset for exploring community ecology without learning species identification.

Our game-to-class pipeline approach was the subject of a pilot program for introductory and advanced undergraduate students from Columbia College Chicago (Chicago, IL) and Columbia University (New York, NY). The Chicago students – enrolled in an ecology course for non-majors – used their species datasets to learn the basics of data manipulation (graphing, trend lines, etc). Meanwhile, the New York students – enrolled in an upper-level class – studied community similarity, turnover, and species accumulation curves.

Materials from both the introductory class and the advanced class can be found online (Davis-Berg *et al.* 2017). After data collection, the introductory-level students (1) created graphs, (2) evaluated their hypotheses, and (3) analyzed and applied their results to ecological concepts. Likewise, the advanced class students (1) identified species accumulation curve inflection points, (2) generated community similarity trees based on Jaccard's distances, (3) quantified alpha diversity using multiple indices, and (4) used non-metric multidimensional scaling (NMDS) to examine biodiversity. Students then compared the patterns visualized in the distance trees to the NMDS plots (Figure 2).

To reflect on the applicability of the assignment, students drew parallels between their results and real-world ecological scenarios. For example, students deduced that more experienced players encountered the rarer Pokémon, akin to highly experienced researchers observing more species during a survey than other observers; Pokémon were also observed in higher abundance between 9 am and 5 pm (fixed for sampling effort), demonstrating how sampling must be directed to account for the behavior of a target species. Lastly, the game programmers increased the frequency of "ghost-type"

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Figure 1. *Pikachu (a charismatic, yellow Pokémon) observed via smartphone at an undisclosed field location. A Poké Ball (spherical capture device) is visible in the screen foreground.*

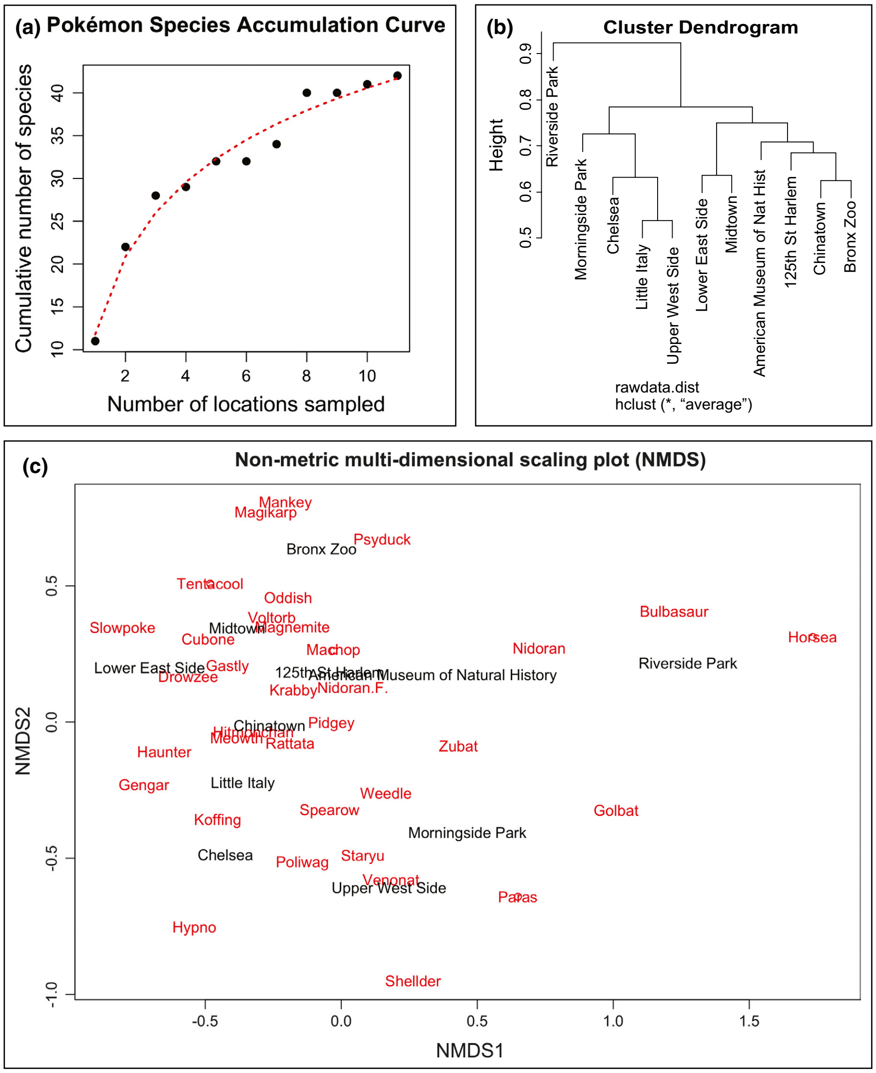

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Figure 2. Examples of community ecology analyses conducted by students: (a) species accumulation curve, (b) community similarity dendrogram, and (c) non-metric multidimensional scaling (NMDS) plot.

Pokémon for Halloween (~90% of all species caught), an analogy for ecosystem shifts with seasonality, migrations, or invasive species introduction.

The success of such a collaborative program was evident, as students demonstrated an improved ability to ask scientific questions pertaining to data. They identified biases in sampling and compared results across procedures and schools. Although there could be issues of technology accessibility, particularly in rural or low-income classrooms (Gilliam *et al.* 2017), game play represents an important technique for diversifying classrooms.

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