A Game-based Approach to Teaching Concepts of Infectious Disease

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Abstract: With over 1,400 known disease-causing organisms in humans alone, and hundreds of named infections, the realm of Medical Microbiology is both fascinating and intimidating. The wealth of information covered in this subject area often demands much memorization that can be difficult to handle. By integrating key concepts and terminology of this subject into a disease-based game concept, student interest and engagement in class as well as retention of information and performance on exams can be greatly improved, however. Here, I will introduce the elements of this game-based activity and several suggestions of how it can be integrated into the classroom to foster active learning as well as greater interaction and communication among students.

Key words: active learning, game, Medical Microbiology, disease, pathogen

Introduction

In more than 20 years of teaching Microbiology and related subjects, one of the areas that always catches my students' attention and interest is the nature and cause of infectious diseases. Every student has, of course, experienced sickness and most have a natural curiosity about the causes of their illnesses. Moreover, frequent headline news reports of significant disease outbreaks such as the recent Ebola crisis in West Africa, cholera epidemics in natural disaster areas, or cruise ship norovirus outbreaks generate much interest in students, and enrolment in my Medical Microbiology course is always good. Students are very interested in what causes disease, how symptoms develop, how diseases can be identified and treated. By searching the scientific literature and cataloguing the different microbial species responsible for disease in humans, researchers in the UK listed >1,400 different species (Taylor et al., 2001) – a huge number were one to try to cover each one in the course of one semester! Yet even the more modest amount of material in an undergraduate course includes roughly 250 different pathogenic species and infections. Various approaches have been used, such as by organ systems affected, symptoms, or by pathogen group – often called the "bug parade" (Murray et al., 2016). The latter approach is very relevant in clinical diagnostics, as isolation and identification of particular pathogens often precedes diagnosis and treatment of an infection. Regardless of approach, students are left to memorize or integrate large amounts of material.

The authors of my favorite text for this course (Murray, Rosenthal and Pfaller) provide helpful suggestions for mastering such information, including the frequent cross-referencing of information and sub-categorizing into more easily remembered groups, such as arthropod-borne or sexually transmitted diseases, exotoxin-mediated infections, hemorrhagic diseases, and zoonotic (animal-harbored) diseases. Understanding such groupings and remembering associated diseases does indeed increase retention of this information and improves understanding of mechanisms, and I have used various strategies to incorporate this into my teaching (review sheets, summary charts, diagrams, cross-linked web pages). But the most notable improvement in student performance and learning occurred with the (gradual) implementation of the "Survivor"-styled game activity in the course over the past 8 years. The goal of this game activity was to increase student interest and participation in class as well as to provide a novel way to integrate key course concepts in one activity. At the core of this activity is a set of disease cards (Fig. 1) which integrate key information about each infectious disease in easily identifiable pictograms and key words.

Procedure

Here, I will describe the methods through which I integrated the Survivor game activity in my course, with suggestions on variations to this activity. I will also introduce the key game elements. A more comprehensive discussion of each game element and its relevance, as well as explanations of core concepts, follows. While I was not successful in garnering interest among Microbiology publishers, I hope you will find these materials to be fun, engaging, and ultimately a valuable teaching tool and I will be happy to share these with you.

At the start of the semester, I divide students up into 3 teams. Team names are usually derived from diseases (Ebola, Lassa, Nipah), and I purchased a set of colorful bandannas for each team. Students begin to interact with teammates early on, and weekly on-line quizzes are announced. Quizzes serve three purposes: to review the week's lessons, to earn team points, and to earn treatment cards (see below). A weekly contest is announced during which 2 players are eliminated from competition. This exercise encourages teams to cooperate, review material together, and work together to answer questions. The quiz is administered via the college's Moodle

platform (it could certainly be given in class in printed form as well). Following each quiz, I calculate team averages. The team with the highest average gains immunity (exempt from the elimination competition), while the other 2 teams each eliminate one member. This process is repeated for the first 8 – 10 weeks of the semester, when all remaining competitors are joined into one new team. At this stage, weekly quizzes award immunity to a single competitor, with the remaining students competing to eliminate 2 more competitors. This continues until the last week of the semester, when all remaining survivors compete in a final game to crown the winner. Adjustments to how many teams are formed, how many students eliminated each week, and how many compete in the semester's finale are made based on class size. You can even tailor the activity in a way that nobody is eliminated along the way. Keep in mind that the goal is to encourage participation and stimulate interest.

I realized very quickly that players who were eliminated did not have much incentive to participate in the weekly quizzes, and therefore include a way for some students to return to the game, based in part on their quiz scores and participation. The weekly quizzes thus were well used by students. Quizzes generally are 10 multiple-choice questions with answer choices randomized and questions randomly drawn from a larger pool of 20+ questions. This broadened the amount of material reviewed, especially if team members worked together. Quiz scores are not part of the students' grade for the course, except to award a small number of bonus points proportional to each student's participation.

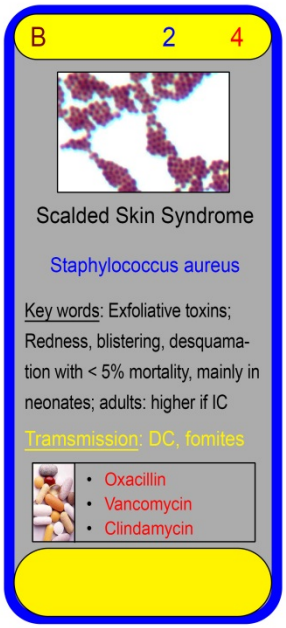

Fig. 1. Sample disease card for Scalded Skin Syndrome

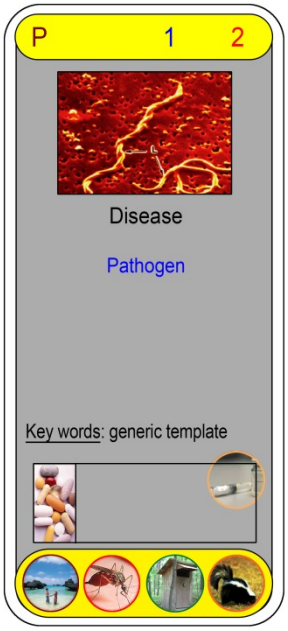

Fig. 2. Disease card symbols and elements

Each elimination contest centers on the two key elements of the game design: disease cards and treatment cards. This is the second area in which students integrate and review information. Each disease card includes key information as shown in Fig. 2: Disease name, cause (pathogen name), mode of transmission, key symptoms, key terms, main treatments available, and special symbols to identify vector-borne diseases, zoonotic diseases, sexually transmitted diseases, food/water-borne diseases and vaccine availability. Each card also identifies the type of pathogen (bacterial, viral, fungal, protozoan or parasitic) and its virulence, represented by a number between 0 and 5 (5 being the most harmful). Each treatment card, in turn, provides students with a means of treating (or preventing) an infection, and thus a way to survive longer in the game. Finally, a third element that can be introduced at any point are so-called event cards, which present variations to the process of infection and recovery, such as exposure to animals, antibiotic resistance or health status of a patient.

Students who participate in the weekly quiz earn treatment cards based on their quiz score. I usually award 1 card for every point above 5 (on a quiz worth 10 points), and players get between 0 – 5 cards. These are shuffled and randomly distributed. As there are 108 cards, students usually get very different ones. Although having more cards increases one's chances of doing well, it does not at all guarantee having useful ones!

Elimination contests are based on a simple premise: play continues until a player reaches a set number of points (the sum of all the virulence scores of any diseases the player has received, minus any that he/she has successfully treated), usually 10. Disease cards are shuffled and randomly distributed among players; the number of cards handed out to each player can be varied based on how quickly the contest must be conducted. The game features 180 distinct disease cards, thus assuring an almost completely random chance of ending up with each disease. If time allows, I start with only 1 card per student, meaning that nobody is eliminated right away. Students who have a treatment card that exactly matches a listed treatment on their disease card can get rid of that disease. Once every student has treated (or prevented) what they can, a second round of cards is distributed. Students now add the virulence points on their remaining cards and attempt to treat/prevent what they have. If a student has reached 10 points, he/she is eliminated (a rare but not unheard-of event after 2 rounds in my experience with this game!). The manner in which new cards are distributed can vary from simply handing out a card to each player to using the game board. I use the former method if only a few minutes are available (i.e. students cannot stay after class), and the latter at later stages of the game when I can schedule a special time and student interest is heightened. An additional variation that is added to the game is the use of event cards, which can be given out randomly (1/student) or uncovered via the game board. These cards present unusual situations or events by which a player may immediately receive or get rid of a disease, gain or lose treatments, gain or lose points, or alter their health status. For example, uncovering a card that states the player is bitten by an arthropod immediately allows another player to hand them a disease card with the vector symbol (mosquito) on it. In this way, disease points can change very quickly.

In contests where only 1 or 2 players are eliminated, contests usually end quickly (within 3 or 4 rounds). The biggest drawback to this method is that contestants have very little control over the outcome of the game: they try to match treatments to diseases, keep track of their points, and hope the next randomly drawn card does not put them over the top (10 points). I have tried to relieve this issue to some extent by introducing event cards between each round, in which case contestants interact with each other by handing off disease cards based on the event described. The use of the game board (Fig. 3) adds significantly more variation and random elements such as when new disease cards are picked up, when event cards are drawn, and when players interact directly. However, this demands more time (15+ minutes). Other variations which have not been tried include allowing students to choose one or more treatment cards before the game, or answer a question during the game to avoid drawing another disease card.

Fig. 3. Laminated game board with decks of disease cards, treatment cards and event cards

Assessment

Student engagement in the course, performance on graded assignments and tests, and voluntary feedback have served as a partial measure of the impact of this activity. In turn, exam performance and "survivor" quiz performance also help to assess student comprehension of the material being taught.

Exam performance: I have typically given 4 exams, 2 of which cover general material and concepts, and 2 which cover the detailed information targeted by this game activity, such as case studies, disease summaries, unique modes of transmission etc. Exam performance for the first 2 tests was slightly improved (80.6 to 81.5) since implementation of the game, but performance on the last 2 exams significantly improved (73.6 to 81.9) in that time (Student's t-test, $P < 0.01$). Although the sample size is small, I find the marked improvement on the later exams to be significant, in part because students previously struggled more with this part of the course. **Feedback**: Student comments about this course have generally been highly favorable, as students clearly were interested in the subject. But the specific comments about the Survivor activity indicated that many students really enjoyed the game,

which was mentioned specifically at least 5 times. One student commented: “The game he made (the details of immunity, bandannas, membership cards, etc.) was great!”. Another student’s comment points to the challenge of learning this material: “To really understand some parts required a lot of learning of new names and details to general concepts. It was more finding a way to piece intimidating loads of data together in useful ways to identify causes in case studies and other ways to categorize diseases”.

Participation/engagement: Student participation in the optional “survivor” quizzes was around 90% for each of the past 3 times the course was taught. By comparison, optional bonus point assignments in my General Microbiology course have a participation rate of only ~50%. Students seemed to really want to participate, especially during the team competition phase. It is not unusual for students who are not competing to watch a competition among others, or for one student to feel bad for another if they are eliminated – and usually, competitions are accompanied by good-natured ribbing and laughter.

1. Participants get treatment cards as before, based on Survivor quiz scores
2. Contest is conducted on the Survivor game board
3. Each contestant starts with 2 disease cards. Contestants start on fields numbered 1 – 8
4. Contestants take turns rolling dice and move clockwise. Actions depend on the field a contestant lands on:
    - Numbered field: pick up one disease card
        - You may treat any disease you pick up with the specific treatment if you have it
    - Field designated B, V, F or P: get a disease card specific to the pathogen class (bacteria, virus, fungi, protozoa – see pictures below)
        - If you have a treatment card for this category, you may play it to prevent infection; no disease card is picked
        - If you pick a card first, only the treatments indicated on the disease card may be used
    - Syringe: pick up an event card and read it out loud. Follow the action
        - If you contract a zoonosis, vector-borne disease, STD, HAI, Bioterror agent or food/water borne disease, the first opponent to place a matching disease card on the table passes it on to you
    - Outhouse: you contract a food/water borne disease from the first opponent to place it on the table
    - Mosquito: you contract a vector-borne disease from the first opponent to place it on the table
    - Beach couple: you contract an STD from the first opponent to place it on the table
    - Skunk: you contract a zoonosis from the first opponent to place it on the table
    - Pills: you get a free treatment card
    - Hospital: you get rid of one disease card of your choice
    - Picnic pond: skip a turn
    - H: go directly to the hospital
    - Blank field: nothing happens
    - IC/HIV: you become immunocompromised, and immediately use the red numbers in place of blue numbers (If only blue numbers are present, you still use these)
    - Shortcut: you must follow the shortcut path on your next turn. You may choose which way you go at forks in the path, but you may not backtrack. Once you reach the edge of the board, proceed clockwise again. If you land on the shortcut symbol on your way out, stay on the edge.
5. If you land on a space already occupied by another player, you may give one of your diseases to your opponent. Then follow instructions on the field you landed on.
6. Special rule: You may play a numbered treatment card instead of rolling the die when you are on the outer track. You now move ahead by the number of spaces matching the # on your card. Your treatment card is turned in. All other rules apply.
7. If a player reaches 10 points at the end of a turn, he/she is eliminated

Table 1. Survivor board game rules

Discussion

The Survivor – Pathogen Island game incorporates many key concepts into its design. The following terms, concepts and principles of medical microbiology are all incorporated into each disease card and can be further elucidated and illustrated through the additional use of the game board, treatment cards, and event cards. Table 1 explains the rules of the game. No matter how you choose to use the game, you will find many opportunities to launch a discussion or emphasize a key point in the midst of every game activity!

Pathogen types: Infectious diseases in humans are caused by > 1,400 known pathogens, which includes bacteria, viruses, fungi, protozoa, and parasites. Each disease card is color-coded by these main categories and includes an identifying letter for each. Every card also includes a specialized symbol for each specific class within these categories. For example, bacteria are divided into Gram-positive rods, Gram-positive cocci, gram-negative rods, Gram-negative cocci, Gram-negative curved/spiral bacteria, and unusual/intracellular Gram-negative bacteria

Virulence: The seriousness of any infection is the product of several factors, including the virulence (nastiness) of the pathogen, the ease of infection, the number of infecting microbes, and the host's immune system. I have taken these factors into account to generate a relative virulence number, which is printed in blue on the top of each disease card. Numbers range from 0 (harmless) to 5 (extremely harmful).

Immunocompromising conditions: Many infections are made more serious if a host has a compromised (deficient) immune system. This may be due to genetic defects, HIV infection, immunosuppressant drugs, or even age and malnutrition. This concept is integrated into an upgraded virulence number, printed in red next to the relative virulence number for infections where it applies, and indicates to students the significant impact of such immunocompromising conditions.

Biohazard: Certain infectious agents are classified as potential bioterror agents by the CDC (CDC, 2018). Such agents include anthrax (Category A), Typhus fever (category B), and hantavirus (category C). Pathogens in these categories are identified with a special biohazard symbol.

Disease name: Many infectious diseases have one specific cause and unique symptoms; the association between disease and pathogen is obvious (e.g. anthrax – *Bacillus anthracis*). However, the majority of infections that occur in humans have a less precise correspondence to one particular pathogen. Many infectious agents have multiple anatomical manifestations (e.g. Staphylococcus aureus – impetigo; toxic shock syndrome; scalded skin syndrome; carbuncle), while some infections are named by the anatomical location where they occur and have multiple causes (e.g. pneumonia – Klebsiella pneumonia, Mycoplasma pneumonia, Streptococcus pneumonia). This concept is reinforced as students encounter multiple cards with the same pathogen or the same disease name but different corresponding disease/pathogen.

Pathogen name: In addition to the above-mentioned concept of pathogens having more than one potential effect (disease), the nomenclature of microorganisms is reinforced. Bacteria, fungi, and protozoa/parasites follow the binomial system on nomenclature while viruses are more generically named and categorized by structure, size, host range and replication pattern. Relationships between certain pathogen groups emerge as well as students recognize certain Genera as causing multiple diseases, and when appropriate, a pathogen's Family or larger taxonomic level may also be indicated in the key words.

Pathogen image: Recognition of a pathogen and laboratory diagnosis of an infection often involves microscopic observation, and in some cases this alone may be sufficient for an accurate diagnosis (e.g. Giardiasis – *Giardia lamblia* has a very unique shape). In other cases, the shape and/or color may narrow down the possibilities. In combination with the pathogen type information (symbol/letter in the top section), a clinical diagnosis is much more likely with this information. Likewise, it becomes much easier for students to remember and identify certain diseases if they are narrowed down to one specific category (e.g. spiral-shaped bacteria). Lastly, visual association of a pathogen's image with its name and disease reinforces learning and aids in case study identification where images may be given.

Key words: Each disease card features important terms that should be associated with the infection. This includes key symptoms (e.g. flaccid paralysis – Botulism), unique reservoirs/animal associations (camels – MERS virus), key complications (Weil's disease – rat bite fever), diagnostic clues (owl's eye inclusions for Cytomegalovirus), alternate names (Athlete's foot – ringworm), geographic areas of prevalence (Ohio/Mississippi river basins – Histoplasmosis), and more. Remembering even one key word may be enough to trigger recollection of disease or pathogen names and other associated data.

Transmission mode: The most common mode of transmission is identified for each pathogen. In some cases, multiple modes exist. Common modes of transmission include direct contact (DC), inhalation/respiratory, ingestion or fecal/oral route, vector (e.g. insects, ticks), and trauma. Grouping diseases by unique modes of transmission facilitates retention of information, helps understand geographical incidence of certain infections (e.g. mosquito-borne), and highlights prevention efforts.

Special categories in terms of transmission mode include sexually-transmitted infections, arthropod-borne diseases, food/water-associated pathogens, and zoonotic (animal-associated) microbes.

Vaccination: Availability of a vaccine for a particular disease is indicated on these cards with a vaccine symbol in the corner of the treatment box. The concept of vaccination is not new, but needs to be emphasized particularly now, when many preventable infections (influenza, mumps, whooping cough, polio) have re-emerged due in part to public misconceptions about vaccines. The effectiveness of vaccination is built into this game by using vaccine cards (one of the treatment card options) to completely prevent a disease.

4) antimicrobial resistance is a real and present danger to our efforts to combat and treat disease. This idea is reinforced through a) the lack of available treatments for some diseases and b) special "event cards" which introduce resistance and antibiotic expiration.

Sexually transmitted diseases/infections: A special symbol (beach couple) is present on cards for STDs, allowing students to quickly identify (and hopefully remember) these diseases as well as recognizing ways to prevent these infections. Prevention of STDs is also incorporated into the game via "Abstinence" treatment cards. Students learn to recognize STDs by name; understand that STDs can include viruses, bacteria and protozoa; realize that new information has come out which adds some diseases to the list of known STDs (e.g. Zika); and recognize the collective burden of STDs. While STDs are often relatively "mild" compared to terrible diseases such as tetanus, they are much more common and therefore present a greater impact on society as a whole.

Vector-borne diseases: Each vector-borne disease features a special symbol (mosquito) on the bottom of the card, helping students quickly identify this category of diseases. The specific vector is often identified in the key terms or transmission section. Students learn to associate diseases with their vectors, and follow-up questions can easily reinforce this concept (e.g. "How many other pathogens do you remember that are transmitted by ticks?"). This concept is further incorporated into game play using the game board and event cards, both of which feature the mosquito symbol. Prevention of transmission is also addressed with the use of "Bug spray" (insecticide) treatment cards. Yes, I know not all bugs can be repelled this way, but the concept works in the game setting!

Food/water-borne diseases: A special symbol (outhouse) represents this category of diseases. Such infections may be transmitted by contaminated food (can be specific or general), water, or fecal-orally.

Treatment: Each card features a black-bordered box with some of the major treatments (primarily antimicrobial drugs) listed which are effective against the particular infection. This aspect of microbiology is built into the game through the use of treatment cards (a separate set of cards with a playing card theme). Several key concepts are emphasized: 1) antibiotics are effective only against bacterial infections (with rare exceptions); 2) antiviral, antifungal and anti-parasitic drugs are needed to treat these respective infections, and the number of such drugs is fairly small; 3) many different infections respond to antibiotics differently; one pathogen must sometimes be treated with different drugs depending on body location, resistance, or duration of infection.

This often represents an additional important epidemiological consideration to diseases normally not associated with food (e.g. Toxoplasmosis – usually transmitted by cats). Students will learn to recognize that this mode of transmission is wide-spread, common, and a significant challenge for prevention. Event cards and matching game board symbols further integrate the concept into the activity.

Zoonotic diseases: The special (skunk) symbol represents diseases which maintain an animal reservoir. This helps to reinforce the concept of disease reservoirs and distinguishes these diseases from those with strictly human reservoirs (e.g. gonorrhea) or environmental reservoirs (e.g. tetanus). Although transmission mode varies widely among these diseases (bites, ingestion, touching, inhalation), animal contact in some form is often an identifying clue for these diseases and should always be inquired about in trying to diagnose an unknown infection. Furthermore, unique animal reservoirs may be associated with some diseases (e.g. leprosy – armadillos) and make for interesting case study material. Again, this concept is also built into the event cards and the game board.

Event cards and the game board (Fig. 3) furthermore add the following elements to the game which reinforce additional key terms and concepts in microbiology:

Healthcare-associated infections (HAI): Also known as nosocomial infections, people become susceptible to them in hospital/health care settings. This concept is integrated into the event cards as an optional element.

Antibiotic resistance: Many microbes evolve to become resistant to treatments, including superbugs such as MRSA, CRE and VRE, all of which have made the news lately. Resistance is included as an event card.

Health of a host: Immune defenses and ability to fight off infections are improved in a healthy person and lessened in a weakened host. Event cards

can add points due to weakening of the body (fever, inflammation) or subtract points (healthy diet). Furthermore, event cards and game board spaces designated as immunocompromised ("IC") force a player to use the red numbers on their disease cards, reinforcing the concept that the immune system plays a critical role in the defense against infection.

Potential game variations: I hope you'll find new, innovative ways to combine the elements of this game activity with new ideas, and that you will feel free to share with me your successes and failures. One could print out (or computer-generate) a random question a student would have to answer if they land on certain fields, for instance, instead of separating the questions from the game as I have done.

Medical Microbiology is a daunting subject when one begins to consider the vast number of pathogens and infections to be learned – but it does not need to be. Games are often fun, entertaining and engaging – and have limited educational value – but they don't need to be this way! By combining key terms and concepts from my course and competitive class activities within the context of a comprehensive game, I have seen increased student engagement, improved exam performance and more excitement among students.

Acknowledgements

A short article published in Microbe in 2006 served as a seed to plant the idea of a game involving microbes in my head (Casadevall, 2006). I am also grateful for the many encouraging comments from students regarding the game design and implementation.

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