Using Game Theory to Design Problem-Solving Exercises

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THE CHALLENGE

One of the foremost challenges facing veterinary pharmacology educators is to keep our students actively engaged in the learning process so that they will acquire basic knowledge, understand complex concepts, and develop an interest in the subject that will extend beyond the terminus of the course. We know that our students are capable of such focused activity because we see it when they play computer games, visit the video arcade in the mall, or engage in their favourite gaming pastime. Unfortunately, most traditional methods of disseminating information (lecture, etc.) rarely achieve this degree of focused attention. The use of classroom simulations, computer assisted instructional programs, role playing, and other educational "games" may be one way to "capture" this level of intense focused attention while delivering the instructional material and developing problem solving skills.

We have all experienced, or perhaps created, simulations or educational "games" in which the students actively participated and appeared to learn a great deal. We have also probably experienced the other extreme where the exercise was dismissed by the students as boring, contrived, or a waste of time. Because the student's perception of the educational value of the exercise usually gravitates to the extremes with few simulations ever leaving the student with an ambivalent opinion. Therefore, it is very important that the educator who develops simulations or games for the purposes of enhancing problem solving skill development be somewhat familiar with the basic tenets of game theory.

GAME THEORY

Game theory is a collection of ideas and tested hypotheses about why some classroom simulations or problem solving activities ("games") are viewed as positive learning experiences while others leave the student bored and loathing the exercise. Although game theory research spans many educational fields, there are some key components that the simulation or game developer can use even with their first attempt.

Three Basic Elements to be Considered

There are three elements that affect the outcome of every learning game or simulation: 1) characteristics of the participants, 2) characteristics of the content material, and 3) characteristics of the "game" itself. It is the interplay of these three characteristics that determines the success or failure of the activity. For example, even the best written activity (game characteristic) dealing with a relevant and controversial topic (content characteristic) will fail miserably if the student is not motivated because of a test in the next hour's lecture (student characteristic). It is therefore important to take into consideration all three factors when developing a simulation or other problem solving activity.

Of the three basic elements, the characteristics of the student participants is the component that is most variable and unpredictable. It is very important that the developer have a clear understanding of the capabilities of the students that will be involved in the simulation (computer skills, level of knowledge, learning styles, prior experiences). Because this component of the three basic elements changes to some degree each day, the best a simulation developer can do is target the "average" student and develop flexibility within the simulation to accommodate students that fall slightly to either side of this average.

An easy way to ensure that students have adequate mastery of "entry level" knowledge, skill, or content familiarity is to utilize a pre-test. Students who are unable to complete the pre-test at a pre-set mastery level are requested to review information, content, or develop a skill prior to attempting the simulation. Again, this type of pre-test is only effective if the developer understands where the target student audience is as far as competencies. An important rule of thumb is: Focus on where your students are, not on your idea of where they should be.

Motivating the Participants

Educational research has shown repeatedly that motivated students are more likely to learn and retain information than unmotivated students. Therefore, a successful problem solving activity or simulation should provide an element of motivation in order to actively engage the students in the exercise.

Motivation is often broken into two broad categories: intrinsic motivation and extrinsic motivation. In simple terms, intrinsic motivation is that drive that comes from within ourselves and is sometimes labelled as curiosity, interest, play, or gratification-seeking behaviour. Intrinsic motivation is what keeps students (and faculty) at computer games or video arcades for hours at a time. Intrinsic motivation is also what keeps many veterinary students struggling for hours to "solve" a complex simulated case when they "should" be doing other studying. A student who is intrinsically motivated wants to do the activity.

In contrast to intrinsic motivation, extrinsic motivation, as the name implies, is motivation that originates from outside of the self. Examples of extrinsic motivators would be grades, money, or threat (a negative extrinsic motivator). By using grades or the threat of failing a test, faculty are able to "motivate" the students to perform in a system in which the rewards and penalties are well understood by both sides. Unfortunately, a student who is extrinsically motivated may not really want to do the exercise, but feels the need to so as to get a reward or avoid a "punishment". Therefore, extrinsic motivational rewards do not usually engender the student's desire to learn a given subject content after the extrinsic motivator has been removed (i.e. the course ends).

Although extrinsic motivational factors are much easier to incorporate into a problem solving exercise, studies in motivational research have shown that extrinsic motivation (money, grades) may actually extinguish intrinsic motivation (curiosity, pleasure, fun). In one study students were allowed to play a computer game for "fun" (intrinsic motivation) and their number of hours "on-task" recorded (Deci, 1971). At one point during the study one group of students was told that for each game that they won, they would be paid a certain amount of money (an extrinsic motivator). The other group served as a control. After the point where the extrinsic motivation was introduced to the one group, the number of hours those monetarily rewarded students engaged in the previously enjoyable (intrinsic motivation) task dropped significantly. The students who were not paid still engaged in the computer game for fun and showed no significant drop in hours of participation.

In a similarly constructed study, students extrinsically rewarded decreased their hours of time "on-task"; however, their number of hours spent on the game recovered to its previous level after a period of time (Lepper & Greene, 1978). Thus, it would appear that the extrinsic reward is detrimental in an intrinsically motivating task but the extrinsic reward effect can be short-lived.

By substituting the word "grades" for "money" in the previous examples, we may suggest a partial reason why students claim that their intrinsic curiosity for a given activity wanes once they know a grade will be assigned to their performance.

GOAL SETTING

It has been observed by educators that older students (high school and above) tend do better with simulations in which they are working towards a defined goal. Very young children often prefer games that do not have a defined goal but encourage a random experimentation and exploration. While this is an over-generalization and more reflective of learning styles (Claxton, 1987) than age (e.g. the need for closure, goal attainment versus enjoyment of the process itself) this difference between older and younger participants in games was raised as an issue in a seminar I presented for educators at a community college. As part of the seminar the participants, who were faculty, instructional designers, and medical illustrators, they were allowed to experiment with a very popular children's computer game (Where in Time is Carmen San Diego, Borderbund Co.). The overall consensus of this group of educators was that the format of the game was extremely frustrating because of the lack of direction, lack of defined goal, and poorly described methods for achieving the goal. In contrast, several of the educators who had worked with children described how their students would spend hours enthraled by this same program. There is obviously a factor in these two populations that relates to goal setting that could affect how well a simulation or problem solving exercise succeeded.

Experience and research with learning styles has shown that providing too nebulous a goal can be frustrating to those individuals who derive a feeling of accomplishment and satisfaction from finishing a task. These individuals want to know the "best" and quickest way to the goal so they can attain their intrinsic reward (the sense of accomplishment). In contrast, the individual who is more interested in the "process" and less interested in the goal would probably enjoy a simulation in which the outcome was less stringently defined. Although it is realistically impractical to adapt a simulation to students of all learning styles, knowing this difference in personality and learning styles may help explain the frustration experienced by one group of students while another group of students participating in the same simulation expresses great satisfaction and enthusiasm.

A guideline for setting goals is to create a clear, general goal (such as "keep this animal alive" or "what is the diagnosis") but allow flexibility in how that goal might be obtained in order to provide some degree of exploration, experimentation, or play. Generally, the more narrowly defined the goal (e.g. "keep this animal alive for the next 24 hours without causing the electrolytes to deviate from the normal range") the more narrowly defined the avenues to reach this goal and the less encouragement for exploration and fun.

ABILITY TO REACH THE GOAL

Part of this topic was covered previously under the discussion of goal setting. It is, however, possible to set what appears to be a "simple" easy-to-attain goal, and then construct a simulation or game that creates very difficult barriers to that goal. Thus, setting a goal at a simple or more complex level is one variable, but how easily that goal can be attained is another variable of equal importance.

As a general rule, goals should be relatively easy to attain by the individual who is a novice using the simulation or game, or for the individual who is new to the information content contained in the simulation. As users of modern audio-video entertainment equipment (VCRs, Camcorders, etc.) we know that struggling to understand the basic operation can be a very demotivating experience if the challenge is too difficult. Motivational researchers have repeatedly shown that increasing confidence in the student, especially during the early encounters with the simulation, increases the student's intrinsic motivation to engage the simulation or game.

The ideal situation in a simulation would be to have a goal of perceived moderate difficulty that is fairly easily reached by the first time simulation user. As the individual becomes proficient in the mechanics of the simulation and becomes more knowledgeable of the informational content contained within the game, the goal should be increased and the level of difficulty to attain the goal likewise increased. An example would be to challenge a novice to arrive at a correct diagnosis in 50% of the animals presented (the goal) with no time restraints and all clinical evaluative procedures available (the level of difficulty in attaining the goal). A more experienced individual in the simulation might be challenged with a goal of 90% correct diagnoses while working under limited time constraints and fewer available clinical diagnostic procedures. Thus, a good simulation or game is one that continues to challenge the participant as their level of competency increases.

Increasing the level of difficult too rapidly, or challenging the novice with too great a goal initially, will result in a feeling of failure, dissatisfaction, and an unwillingness to engage in the learning activity. These reactions may be seen as subtle or overt hostility towards the simulation, the instructor who "forced" the student to use the simulation, or as a blanket statement covering all educational innovations in general! At the other extreme, failure to increase the difficulty of the goal commensurate with the developing skills of the participant would result in boredom and lack of motivation to fully engage the learning situation.

FLEXIBILITY OF THE SIMULATION AND THE PARTICIPANTS' CONTROL OF THE SIMULATION

It might seem that the simulation or game that allowed the student participants the greatest degree of flexibility would be the most desirable situation. Unfortunately research, and your own experience with a new multi-functional VCR, CD player, etc., tends to tell us something different. When we first pull our new audio or video device from its packing box, we are not interested in how to set up and use the multi-simplex-matrix-programming function. All we want to know is how to turn the thing on! Novices in simulations are very similar; they just want to know what to do to make the simulation "run".

Once novice participants have learned how to "turn the simulation on and off", they will begin to exercise their options within the simulations. Some students after going through a simulation once will begin to explore and push the boundaries of the simulation while others will be quite content to make only minor variations from the most basic mode of getting through the simulation. The student who is exploring generally exhibits a more "engaged" behaviour and is more likely to achieve the full benefits of the game than the student who learns one "right" way to work the simulation and simply follows that each time.

What factors in the personality might help account for these divergent behaviours. Part of it lies in the area of research dealing with "locus of control". Locus of control may be defined as the individual's interpretation of "Who's in charge here?" or "Who determines whether I succeed or fail?" A person with a very external locus of control believes that "powerful others"
(instructors, administrators, coaches, etc.) or random chance are the primary determinators of whether they succeed or fail. In contrast, a person with a strong internal locus of control believes that the power to succeed lies within their own efforts. As this applies to the exercising of options within a simulation, internal locus of control individuals tend to explore more than individuals with external locus of control tendencies (Pines, 1973; Prociuk & Breen, 1975; Stipek, 1984; Lefcourt, 1982). Interestingly, students who are at the top of the GPA (grade point average) often display conservative, non-exploratory behaviour in simulations. Biondo and MacDonald (1975) suggested that the academic behaviour shown by these "high grades" individuals may reflect a form of behaviour that has allowed these students to attain their goals (grades) through conforming to the rules of academic engagement and avoiding "risky" situations. Perhaps these students would be more exploratory in simulations if the professor of the course stated that the grade would be based primarily on the number of options explored in the simulation.

Realistically, the flexibility of the simulation must be limited to a workable, efficient level. Unfortunately, the more flexibility required within a simulation, the more complex and the more "bogged down" the movement of the simulation becomes. If a simulation goes from giving the participant the option to alter 2 factors with 2 settings each to giving them

3 factors with 3 settings each, the creator of the simulation has to account for an increase in possible combinations expanding from 4 to 9 possible outcomes. Thus, added flexibility or added options increases the complexity of the simulation geometrically! Therefore, a simulation should strike a balance between enough flexibility to accommodate the curious student and the need for the simulation to proceed quickly and be easy to use.

CREATING THE PERCEPTION OF REALISM

For a simulation or game to work, the students must "buy into" the simulation and the role they are playing within it. Failure to do so results in students who are "going through the motions" without really engaging the learning experience.

Transparency in a well planned and executed simulation allows the student to "see through" all the mechanics of operating the simulation and focus on the learning issues involved. For example, a computer simulation in which the student had to memorize multiple commands for each step would not be very transparent because the student had to focus on remembering the commands instead of the learning issues. One of the most significant problems with poor simulations or games is that the participant becomes frustrated with the mechanical operations. In computer simulations this can result from something as simple as a delay of screen displays, slow response to input commands, rigid rules for inputs, operations that are not "intuitive" to the user, or simulations in which it is easy to give the wrong input (e.g. requiring a double click on a mouse versus a single click; requiring correctly typed long command inputs).

The role that the participant assumes in the simulation also contributes to the realism. If the role is consistent with the personal goals of the participant (e.g. they want to be a practicing veterinarian) the participant is much more likely to engage the simulation and enhance the learning experience. It is important that the simulation or game not allow the individual to "step out" of the role. For example, if the participant plays the role of clinical veterinarian, the simulation should not suddenly remind the participant that they are still a student (e.g. The computer responds: "You can't do that because you are not licensed to practice!")

DEGREE OF DETAIL IN A SIMULATION; HOW MUCH OF REAL LIFE SHOULD IT EMULATE?

It would seem that for a simulation to be realistic to the participant that it should emulate the "real thing" in every detail. In contrast to this notion, research has found that too much detail can actually detract from the main learning issues (Dwyer, 1978). For example, an interactive pharmacokinetic program that provides multiple, continuously changing parameters would be overwhelming to most students resulting in decreased motivation and less efficient learning. Instead, simplifying the simulation to initially including only single parameters allows the student to grasp some basic concepts before they tackle integrating more complex interactions.

Another example of where the real thing is less effective than a scaled down model is where actual video is used as opposed to simplified graphics. In viewing a video of a horse with lameness, there are a number of distracters present in each video segment that can detract from the novice's ability to focus on the critical points. A simplified graphic, however, would eliminate this visual "noise" and allow the student to focus on the critical elements of the lameness exam. As the student becomes more proficient in the skill and has learned to focus their observation to key elements, the transition can then be made from simplified graphic to full motion video of a horse to observation of an actual animal.

COMPETITION

Competition within a simulation is a factor that can enhance the learning experience or, if misused, markedly detract from it. As a general rule of thumb, little competition should be used during the initial stages of simulation. In these stages the participant is struggling with the mechanics of the simulation and not focused completely on the learning issues. It is therefore very easy for a "competitor" to defeat his/her/its distracted opponent. By allowing the participant some early success in the early stages of the simulation, this prevents frustration and builds a modicum of confidence. At this point competition can be introduced as a means to enhance the motivating appeal of the simulation. Ideally the difficulty of the competition should increase corresponding to an increase in competency. This is a commonly used technique in popular video games in which the participant advances to the next "level" which contains increasingly difficult challenges. In this case of the video game, the competition is usually against the computer (or at least graphically created monsters or characters) or against one's previous score. A similar motivational competition can be used in veterinary medical simulations in which the participant competes against another student to arrive at a diagnosis, or where he or she competes against the computer to reach a medical goal within a certain period of time.

Perhaps an easy and conservative way to utilize competition is to allow the student to select the level of competition themselves. This accommodates student learning styles that thrive on internal or external competition while providing an environment that is not threatening to those learning styles that are competition-averse.

DEBRIEFING

One of the critical elements for successful simulations and educational games is the debriefing period after the simulation has concluded. From the instructional developer's side this debriefing is critical for identifying factors that impaired the flow of the simulation (issues of transparency, realism, flexibility, etc.). From the educator's view debriefing helps the students to focus on the learning issues. There are a variety of auxiliary learning issues involved with any simulation or game (e.g. working with others, dealing with failure, learning to be decisive, etc.). The debriefing helps the student to sort out the core learning issues from the variety of auxiliary issues that occurred during the simulation. In addition, it gives the student a chance to vent frustrations (e.g. "The computer acted so stupidly!") and a chance for the instructor to correct misconceptions resulting from student-created hypotheses during the simulation. A successful debriefing helps ensure that the student participants view the simulation in a positive light so that they will be encouraged to participate again.

HOW DO I KNOW IT WORKED?

Evaluating the educational impact of a simulation usually involves two elements: content/skill acquisition and student attitudes. The latter, often referred to as a "smile test", is usually conducted during the debriefing or via a simple written attitude survey. Although the attitude results are qualitative ("soft") data, they can provide excellent insight into transparency, realism, and the degree of flexibility of the simulation or game.

The content assimilation by students is generally more quantitative, however, the numbers generated must be interpreted in light of the simulation's objectives and the method of testing and evaluation. If the objective of the simulation was to learn a defined body of knowledge, this can be tested through traditional recall or recognition tests (essay, multiple choice, etc.). If the objectives were focused on motor skills, then testing must involve manipulation or skill demonstration.

If the objectives entailed development of "decision making skills" the instructor and simulation developer may be hard pressed to document actual acquisition of this skill in a way that can be numerically defined. An indirect measure of "successful" decision making skills can be the number of positive outcomes from the simulation (e.g. the number of patient's correctly diagnosed or successfully treated) or the amount of time used by the participant to solve problems. Another method of evaluating acquisition of these skills might be to use an interview in which the student explains the steps he or she used in solving a given problem. Unfortunately, the interview process is extremely subjective and evaluation of the acquired skill difficult to quantify by this method.

Creating effective and valid evaluation methods involves an entire branch of educational research. There are no simple answers beyond the general guidelines presented here. For further information the reader is referred to any number of sources that describe testing and evaluation of health profession and college students (Neufeld, 1985; McKeachie, 1969; Cox, 1982).

CONCLUSION

Simulations and educational games can be valuable learning resources. When well thought out and executed properly they can be an enjoyable learning experience for both student and instructor. Proper execution is dependent upon characteristics of the student in combination with the simulation itself and the instructional content. By keeping in mind the key elements presented an instructor can evaluate the potential success for a simulation prior to its use or can modify/create a simulation that has greater odds for being successful.

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