# CELLS AT WAR: THE PLAYFULNESS OF GAME-BASED LEARNING

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# Contents

# Abstract

After many years of trying to adapt to educational innovations of the 21st Century, educators will soon be looking into the not-too-distant future to consider what modern learning in post-secondary education will look like in the 22nd Century. Technological advances will continue to transform the landscape of the classroom. The use of digital games, although a source of controversy and debate, will prove to be highly effective instructional tools that will promote problem solving and critical thinking skills. Their use has already started to change the structure of the class in the elementary classroom as they serve to energize and engage students in their learning and improve conceptual understandings, creativity, and imagination. The traditional construct of the classroom has started to evolve, embracing a new way in which knowledge, skills, and attitudes can be acquired. The primary focus of this study was to create and implement a biological video game that focused on a single gene disease, which served as a vehicle to teach cellular and molecular biology concepts. 'Cells at War' is a collection of scientific video games developed through interdisciplinary efforts that reinforces the notion that video games are highly effective tools used to enhance instructional methods and engage students in the biology classroom.


**Key Words: Game-Based Learning, another, another**

# Literature Review/Proposal

## Gamification of Learning

Although the use of technology has become prevalent in schools across Canada, using game-based learning as an instructional approach is still in its infant stages. Educators are reticent to embrace digital technology and gaming as the new norm in the classroom due to insufficient technical competence, as well as challenges they face in selecting appropriate games (Jääskä and Aaltonen 2022; Molin 2017). In addition, educators are rarely involved in the development of these games, making it difficult to facilitate suitable learning in the classroom (Molin 2017).

Kindergarten classrooms in Ontario are bustling places of activity, reflective of active inquiry through play. Exploration and provocations drive their curiosity while simultaneously developing their oral language and critical thinking skills (Ontario Ministry of Education 2016). We believe that play is paramount for children in their formative years and educational theorists like Vygotsky affirm this. He was firm in his belief that play is the leading line of development during preschool years (Vygotsky 1967). Unfortunately, in many classrooms, educators continue to feel more comfortable engaging in antiquated and traditional methods of instruction that consist of a didactic approach to learning. Some educators may be fearful that incorporating game-based learning into the curriculum will undermine their authority in the classroom (Jääskä and Aaltonen 2022; Chee et al. 2014; Jong 2016). The need to challenge current educational practices is paramount as it appears some educators are currently teaching students from the perspective of their own past rather than the realities of the students' future.

## What Happens to Play Beyond the Formative Years?

The need to engage and motivate learners does not cease to be a need in a student's educational career. However, what does become a priority in higher academic years are measurable student outcomes (Ball 2012; Shore 2010; Leather et al. 2021). Tests and quizzes take precedence over the formative process of learning. Assessment of learning (tests and quizzes) dominates an educator's instructional practices which in turn diminishes the value of the experiential learning process (assessment as learning). Assessment methods seem to be based on antiquated teaching practices, which have been influenced by our Victorian educational heritage that is rooted in a persistent view of fear of play (Wood 2013). This rigidity in instructional norms appears to have taken hold in our classrooms which diminishes the value and importance of games in the classroom. Reich (2020) argues that schools are complex and conservative institutions that have little incentive to adopt or test novel approaches.

It can be argued that this fear of play is also due in large part to limited resources and training being provided to educators (Fishman et al. 2014). Teachers require technological and pedagogical supports to develop their understanding of game based learning in the classroom. The expectation therefore to incorporate new and innovative teaching methodologies in the classroom is unrealistic without providing teachers with the appropriate training needed to do so. Incorporating game based learning in

teacher practice is impacted by a lack of professional development opportunities that can systematically guide them in using games for teaching, learning, and assessment (Fishman et al. 2014; Ruggiero 2013; Foster and Shah 2020). In order to develop teacher proficiency in game-based learning, further professional development is required in the form of pedagogical training in order to understand how to develop and utilize game-based learning practices.

## Do Games Help or Hurt Learning: The Debate Over Game-Based Learning

The debate of whether game based learning helps or hinders learning is ongoing. What comes into question in opposition to game based learning is that it serves to act as a source of entertainment and amusement rather than for educative purposes (Lister 2015; Mayer and Johnson 2010). Many individuals associate play with children, and therefore believe that play is trivial and unimportant (Prensky 2001). It appears one does not learn to play, but rather plays to learn. Play is where a spark is ignited and the source in which curiosity is peaked. It is not silly, trivial or irrelevant but has a biological and evolutionary function which has a strong connection to learning (Prensky 2001). It is, as Danny Hillis, founder of Thinking Machines and a former Disney Fellow has stated something every single culture does (Prensky 2001).

Arguing the merits behind the development and creation of digital games for use in post-secondary classrooms can appear effortless. However, what cannot be overlooked at times is that educators spend a great deal of time planning and executing engaging lessons which can become time consuming and onerous. McKeachie and Svinicki (2013) argue that the biggest barrier to the use of games therefore is logistic. Although games can be fun and engaging, we know that our classrooms today are comprised of diverse students with varying needs and a one size fits all approach does not work.

## The Benefits of Using Video Games at the Post-secondary Level

Rules, goals and objectives, outcomes, competition, interaction, and story are what Mark Prensky refers to as the six key structural elements of games (Prensky 2001). These powerful factors are what set games apart from other engaging activities. Traditional forms of educational media lack what video games provide, a high degree of interactivity (Coller and Scott 2009). Video games challenge individuals to work within specific parameters and respond to situations that occur in the game (Coller and Scott 2009). The way in which individuals respond to challenges presented in video games allows them to think critically, strategize, and work collaboratively in an interactive and engaging manner.

Video games are visually appealing, stimulating, and heighten our senses in many ways. We become addicted to the hormone boost our brains receive when we achieve results (Tomáška 2022). They allow us to learn through doing and creating. Like play, upon beginning a video game, one is completely immersed into a whole new world without boundaries (Coller and Scott 2009). Each player is engaged in a creative process where they are free to discover the limitless possibilities contained

within the game. In a school setting, we are often taught there is one solution or right answer or way of doing something. Video games challenge this by giving players multiple entry points and pathways to consider.

The growing evidence of the effectiveness of video games in the classroom is emerging, and the value of game based learning is evident throughout various disciplines. In 2005, Northern Illinois University began teaching an undergraduate course in Numerical Methods using a video game called "NIU-Torcs" (Coller and Scott 2009). Students were observed spending twice the average amount of time on coursework than other subject areas (Coller and Scott 2009). Other games are being developed for nursing education which focus on developing medication calculation skills. This is an area of global concern perhaps due to test anxiety and low mathematical self-efficacy in nursing students (Foss et al. 2013). Further, as a result of the COVID-19 pandemic, educators were compelled to find alternative ways to supplement hands-on learning experiences in an online setting. In a study completed at McMaster University, virtual reality (VR) headsets were used to engage in a 3D laboratory simulation which allowed for open-ended investigations in a range of STEM fields such as chemistry, biology, and physics (Tsirulnikov et al. 2023). Tsirulnikov et al. (2023) noted higher levels of engagement and motivation through these VR simulations. Game based learning not only provides students with infinite possibilities for discovery but sustains student interest, builds confidence, and helps to improve cognition and learning outcomes (Divjak and Tomić 2011).

The long-term positive effects of Game-Based Learning will continue to be researched and studied. Although empirical evidence is slowly emerging but still limited, studies and research to date are proving that Game-Based Learning has the potential to transform post secondary classrooms. A learning environment in which students are able to take risks, explore, discover, fail and try again is achieved through a collaborative and interactive process between student and teacher.

# Materials and Methods

## Study Setting and Context

Results from this study were obtained utilizing a first-year cellular and molecular biology course (BIO1A03) at McMaster University (Ontario, Canada). BIO1A03 provides first year students with a strong cell and molecular biology foundation that is required for most upper level courses in the Faculty of Science at McMaster. Enrollment in BIO1A03 tends to be high, with approximately 700 students taking the course during both the fall (September-December) and winter (January-April) semesters. Due to the lengthy process of video game design, we were limited to collecting data solely from students enrolled in the winter semester for this study.

It is worthwhile to note the current course format of BIO1A03. Prior to 2014, BIO1A03 followed a traditional, didactic format, which consisted of three 50 minute in-person lectures per week, accompanied by a bi-weekly, three-hour laboratory session (Tahir et al. 2022). In 2013, BIO1A03 was converted into a Blended Learning course format, which included independent, self-paced learning through prerecorded modules, and face-to-face learning in the classroom with a heavier focus on

student collaboration and engagement (Tahir et al. 2022). Course content previously delivered during lecture was condensed into two weekly modules which students were required to complete prior to attending in-person lectures. In-person lectures were restructured and minimized to two per week. One of these sessions consisted of a review lecture, where students could clarify concepts they found difficult to understand, while the other focused on applying theoretical concepts that students had learned to a real world concept. In a study highlighting the impacts of blended learning in BIO1A03 at McMaster, Tahir et al. (2022) noted that the majority of students surveyed after taking the course felt that these novel blended learning approaches enabled them to improve general knowledge and understanding of core concepts in cellular and molecular biology.

## Video Game Design/Creation

The conversion to a blended learning approach in BIO1A03 allowed for a seamless transition to online-learning in 2019 when the COVID-19 pandemic began. During this time, the BIO1A03 instructional team began exploring other novel pedagogical approaches which could help improve student learning. The idea of using digital games to improve education has been around for quite some time, however the controversy surrounding video games in this context is still apparent.

In 2021, the BIO1A03 instructional team partnered up with the George Brown College School of Design, and received support from CEWIL Canada (Co-operative Education and Work-Integrated Learning Canada), formerly known as CAFCE (Canadian Association for Co-operative Education), to design and implement an educational biological video game that could be used as an instructional and engaging teaching tool in BIO1A03. A small cohort of McMaster Univeristy Biology students and supervising professors, as well as game designers, programmers, animators, audio engineers, and artists from the George Brown College School of Design were selected to pilot this work-integrated learning project.

Concept development began in September of 2021. In this phase, students from both institutions worked collaboratively to brainstorm concepts for a biological video game that would be both engaging and educational. The theme for the game was centred around single-gene diseases. Biology students from McMaster University were responsible for selecting and researching a specific single-gene disease. This information was exchanged with students from George Brown College, who in-turn provided a wealth of knowledge on how to turn these static, difficult to understand concepts into engaging gameplay mechanics. Students pitched these proposals to supervising professors who then selected the ideas and game elements that best suited the goals of the project. The disease that was selected was Pompe disease, a rare genetic disease that causes skeletal and cardiac muscle weakness due to the accumulation of glycogen within lysosomes. The game envisioned was a shooter type game, where students would be tasked with shooting enzymes to break down glycogen into glucose in order to remove glycogen from the lysosomes. Each level highlighted a different stage of the disease; a healthy individual, early onset pompe disease individual, and full fledged pompe disease individual. Through each level, students would be able to see the effects of having less enzymes to break down glycogen.

The game production phase then began in November of 2021. Students from George Brown College started bringing

these ideas to life through artwork, animation, and programming. McMaster Biology students served as subject matter experts, ensuring scientific accuracy throughout the production process, as well as creating an encyclopedia of important biological concepts that were highlighted in-game. Throughout the production stage, weekly online meetings were held to keep all members updated with progress. Discord was also utilized throughout the entire process in order to ensure open dialogue between students and supervisors, as well as to share game assets and important information. A functioning build of the game was completed in late March of 2021, and was introduced in the final BIO1A03 class of the winter 2021 semester, in place of lecture material. After class, students were asked to complete a survey regarding their attitudes towards the game.

## Study Participants

Students qualifying for participation in the survey included only those enrolled in the winter 2021 semester of BIO1A03. Students were informed about the survey prior to playing the game, through both in-class and online announcements posted on Desire to Learn. Students who did not complete the survey were informed that this would not effect course performance. Those who participated were incentivized by being entered into a draw to win prizes.

## Survey Design: Qualitative Analysis of Student Feedback NOT DONE YET

The survey was developed and delivered through the LimeSurvey® platform. Students were asked a total of 14 questions regarding opinions and attitudes on their current undergraduate education, as well as feedback on game-based learning in the biology classroom. The National Survey of Student Engagement (NSSE) was used as a framework to generate the questions that were asked. NSSE questions assess the extent to which students engage in educational practices in the context of higher levels of learning (NSSE website citation). MORE HERE ABOUT NSSE...

# Results

## Student perceptions of current undergraduate experiences

150 students enrolled in the winter 2021 session of BIO1A03 attended a game-based style lecture and completed the follow-up survey. Students were presented with condensed lecture material prior to completing the relevant level in the game. The idea behind this was to provide a brief introduction of the content to students, and then allow them to further explore these concepts by playing the game.

Participants were asked a series of questions regarding their current experiences as undergraduate science students, as well as questions regarding the benefits of implementing game-based learning approaches into their classrooms. To gain insight into how experience students had playing video games, they were asked to indicate a weekly average amount of time spent playing them (Figure 1). 66 Participants (44%) indicated that they did not play video games, while 53 participants (36%) indicated that they spent between 1-10 hours per week. Only 7 students (5%) were found spending approximately 10-20 hours per week playing video games. It is interesting to note that participants who reported not playing video games also emphasized that the game was 'easy to navigate' and 'very accessible'. This suggests that a lack of experience playing video games did not necessarily limit students' abilities to learn course content through playing the game.

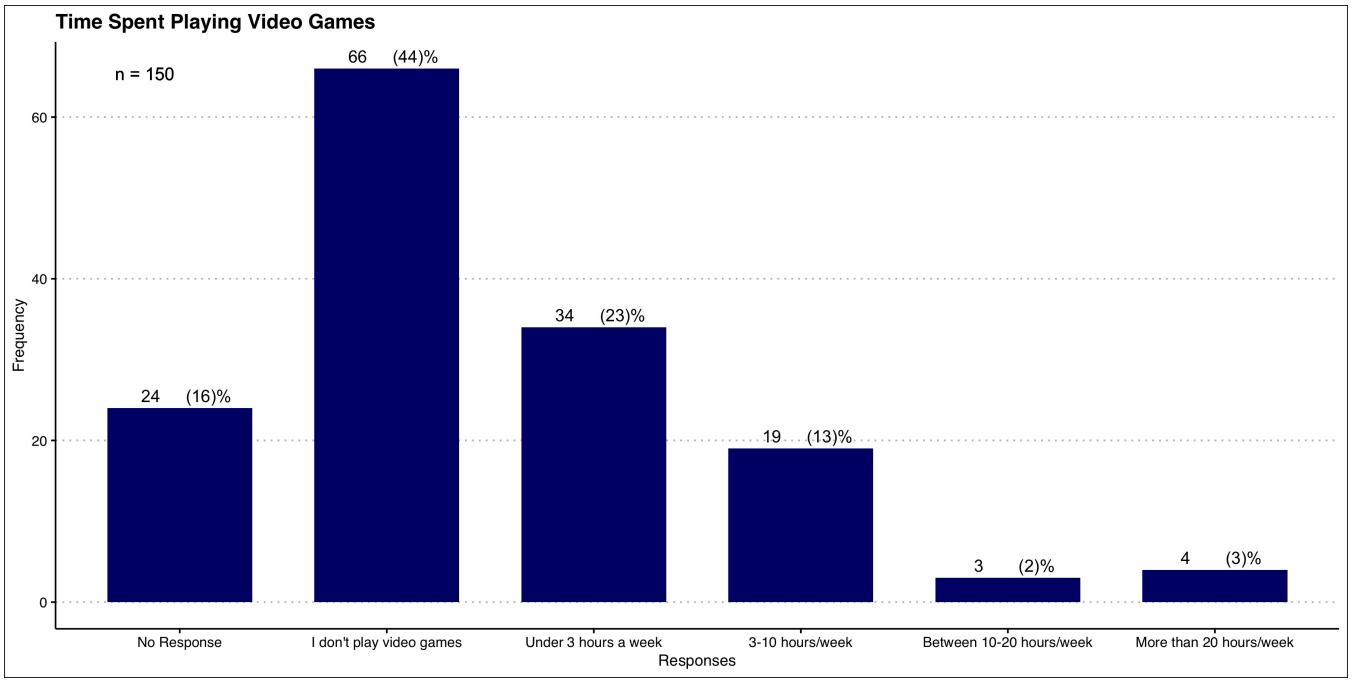


Figure 1: Student responses regarding the average amount of weekly time spent playing video games

Further data obtained provided insight into the various types of courses students were taking at McMaster University during the fall/winter 2021 semesters (Figure 2). At this time, McMaster University was slowly shifting back to in-person

classes due to COVID-19 restrictions being lifted, however, a large majority of courses had been converted to hybrid, blended learning, and online courses. 60 participants (40%) indicated that the majority of courses they were taking were mostly hybrid or blended learning style courses. 28 participants (19%) indicated most of their courses were back in-person, while only 7 participants (5%) were enrolled in mostly online courses. 30 participants indicated a balanced mix of all course types. These results highlight the shift from traditional teaching practices towards more innovative educational practices.

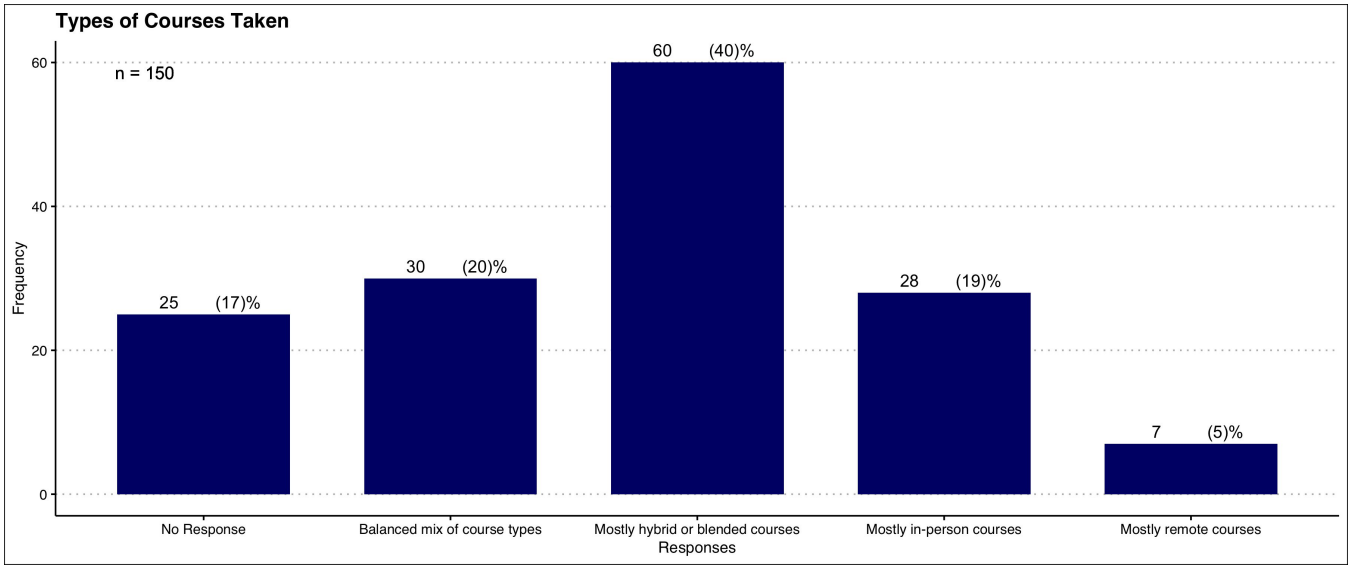


Figure 2: Student responses regarding the different types of courses taken at McMaster University in 2022

Students were asked to reflect on their experiences as undergraduate students at McMaster University. Participants responded to two questions regarding how much coursework has emphasized certain aspects of their learning (Figure 3), and how often they have applied their learning in different contexts (Figure 4). The majority of students responded that their coursework emphasized applying facts to new problems, analyzing ideas in depth, and forming new ideas from various pieces of information "quite a bit". In the case of memorizing course material however, 41% of participants responded this was emphasized "very much" in their courses.

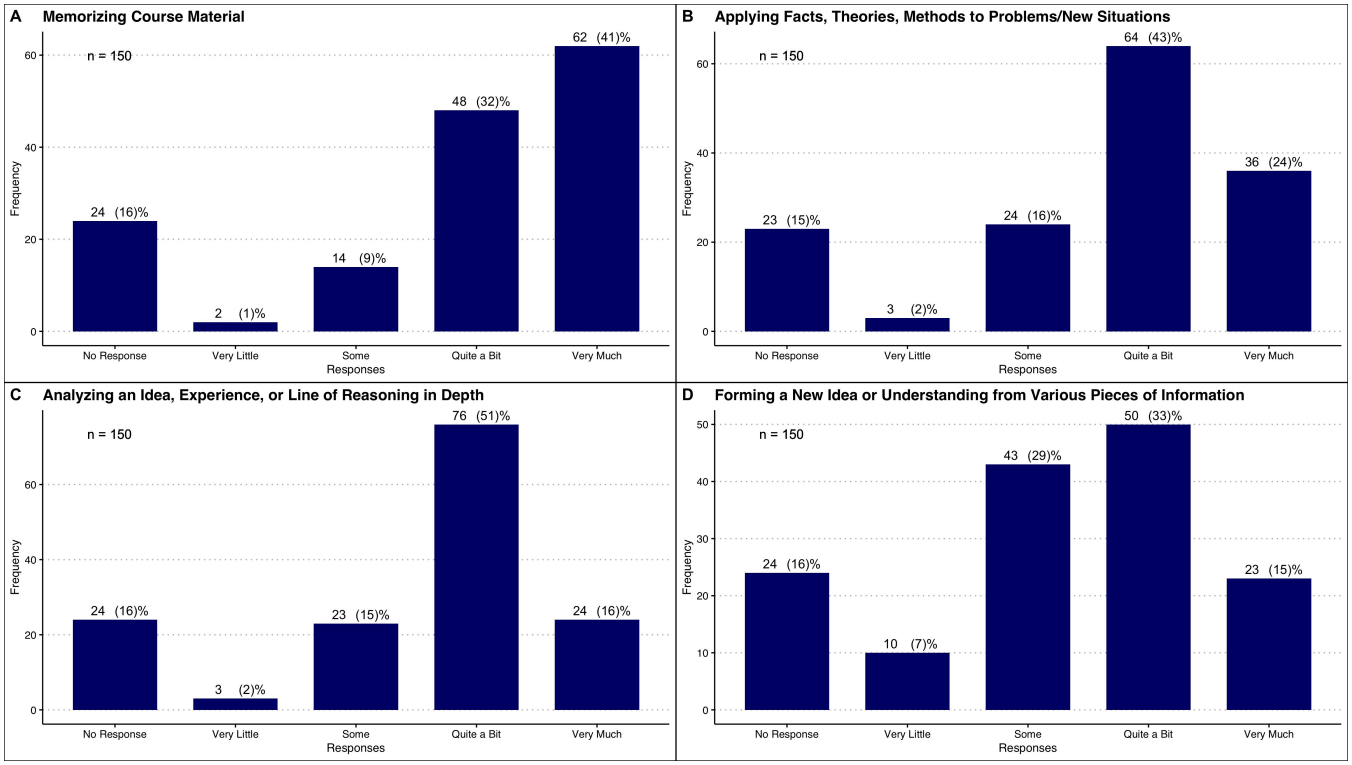


Figure 3: Student responses regarding how much their coursework has emphasized the following aspects

(Figure 4) follows a similar format to the previous question. Students were asked how often they had combined ideas from different courses when completing assignments, connected their learning to societal issues, learned something that changed understanding of an issue and connected ideas from courses to prior experiences and knowledge. Most students responded doing these things "sometimes" or "often", with a smaller number of participants responding "very often". It is worthwhile to note that 43% of students indicated that they "sometimes" connect what they have learned to societal or health related issues. As science students, it is important to connect what has been learned to societal and health related issues, as the concepts we study are interwoven throughout all facets of life. Implementing game based learning into science classrooms has the potential to change this narrative by presenting concepts to students in the form of real world examples, rather than static textbook diagrams.

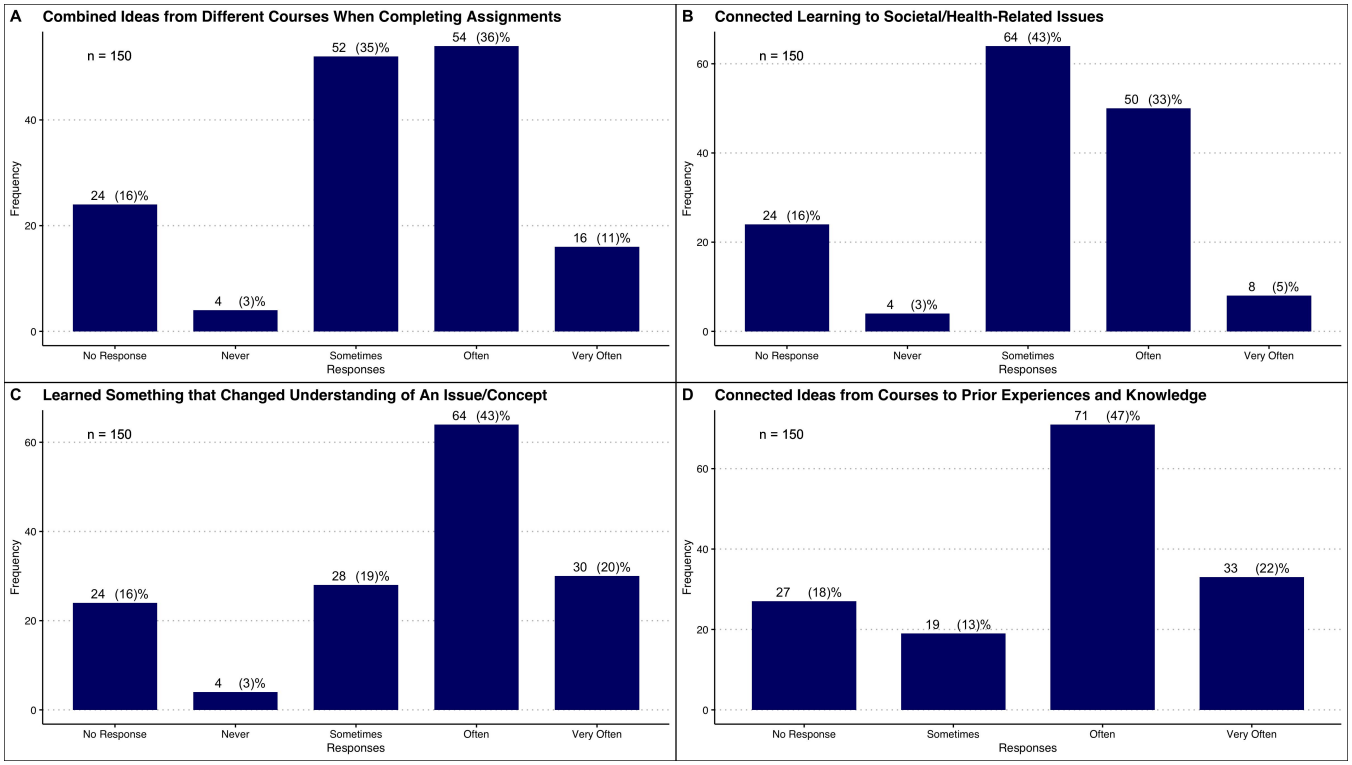


Figure 4: Student responses regarding how often they have done the following things during the school year

## Student perceptions on the use of game-based learning in biology

After the questions regarding current undergraduate experiences, students were asked to reflect on their feelings towards implementing game-based learning approaches into their classrooms.

Following the same question structure as (Figure 4), students were asked how implementing game-based learning into any one of their science courses could help in a wide variety of areas. Interestingly, across all four areas, we see an increase in the number of students who responded "very much", compared to the number of students who responded "very much" in (Figure 4). Through implementing game based learning methods in science classrooms, more students would feel better suited to combine ideas from different courses when completing assignments, connect their learning to societal and health related issues and connect ideas from courses to prior experiences and knowledge. Following the same question structure as (Figure 3), (Figure 6) shows how motivation to do certain things can be improved in BIO1A03 if a game-based learning component was added. In general, students indicated that a game-based learning component in BIO1A03 would improve motivation to connect ideas to societal issues, learn something that changes understanding and connect ideas from courses to prior experiences and knowledge "very much". In comparison to (Figure 3), there is a clear increase in the number of responses which indicate "very much". The only exception however is in terms of motivation to memorize course material. There was a decrease in the number of students who reported that if BIO1A03 added a game-based learning component, it would motivate them to memorize course material. This is exactly the aim of game-based learning approaches, to emphasize exploration and understanding, not memory.

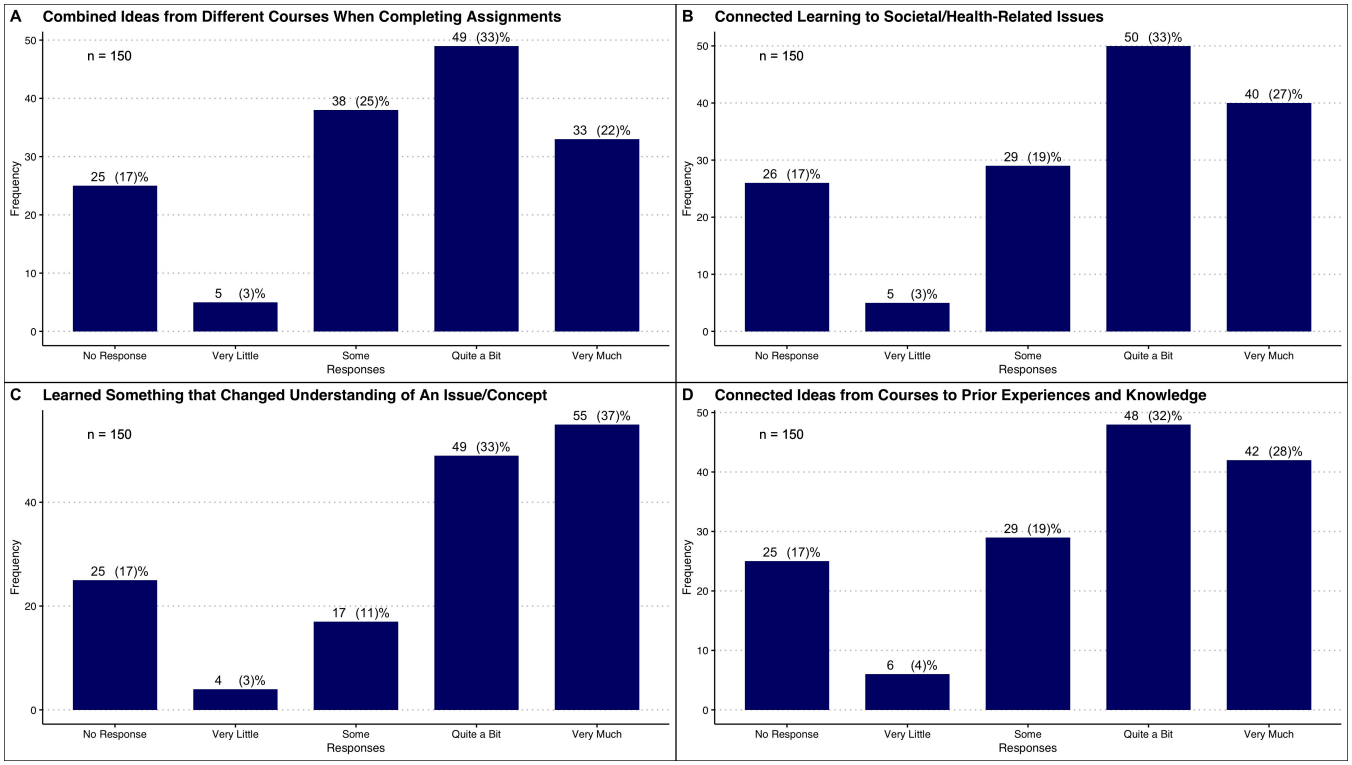


Figure 5: Student responses regarding how game-based learning approaches could help with the following things if implemented in science courses

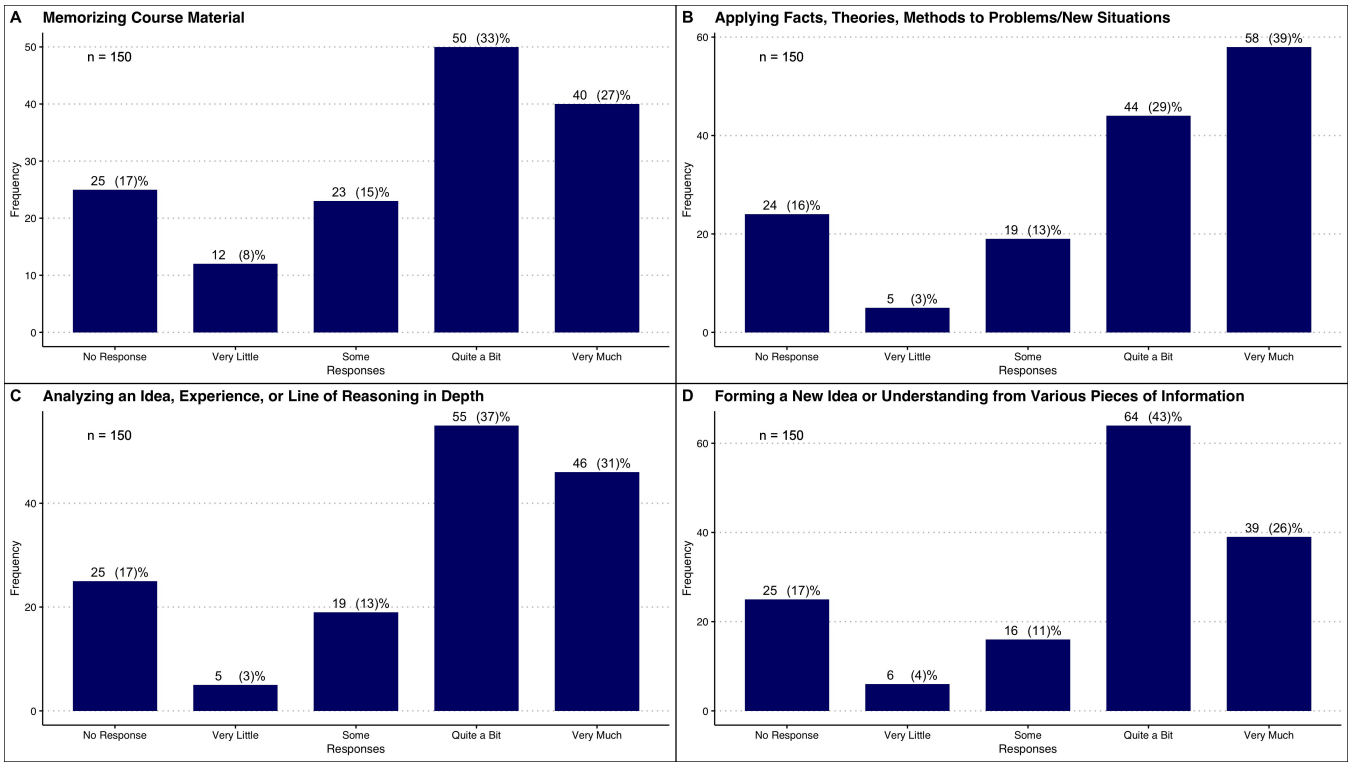


Figure 6: Student responses regarding how motivation to do the following things would improve if BIO1A03 added a game-based learning component

The final two questions provided insight into students' feelings towards not only game-based learning, but specifically towards Cells at War. Students were asked how likely it is that they would play Cells at War outside of class on their own time to further consolidate material taught during class (Figure 7). The results indicated that 43% of students were somewhat likely to do this, while about 17% of students reported being very likely to this. 21% of participants indicated they would not be very likely to do this. These results highlight the potential game-based learning has to be utilized not only as an instructional tool in class, but also as a form of practice and content mastery for students.

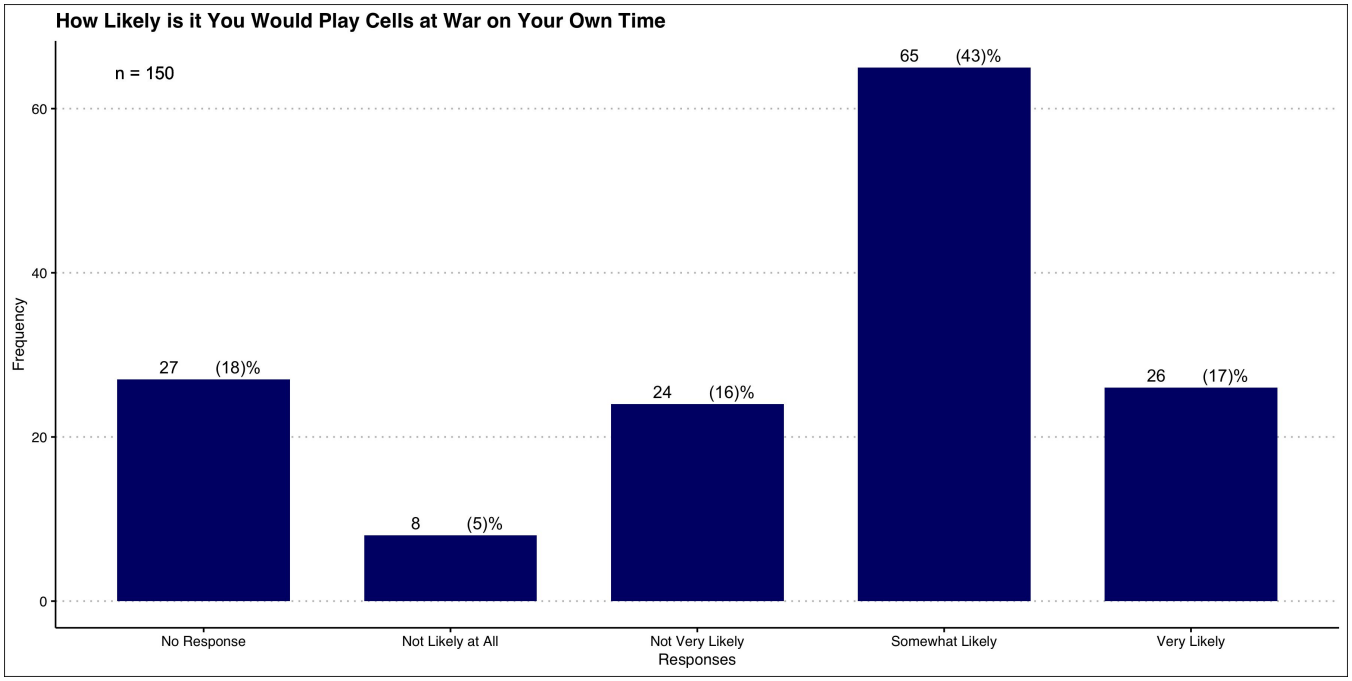


Figure 7: Student responses regarding how likely they would be to play Cells at War on their own time, outside of class to further consolidate material taught during class

To assess if students understood the content shown to them in game, they were asked how prepared they would feel if given a quiz on Pompe Disease based off playing Cells at War, compared to studying off traditional lecture slides (Figure 8). 52% of students indicated they would be somewhat prepared, and 17% of students indicated they would feel very prepared. This strengthens the argument that again, game-based learning is not only an in-class intervention. Video games promote practice, critical thinking, and content mastery, all of which are important aspects when preparing for assessment. Students are willing to try alternative studying methods, and giving them the ability to study in a way that is engaging and interacting could have positive benefits on performance.

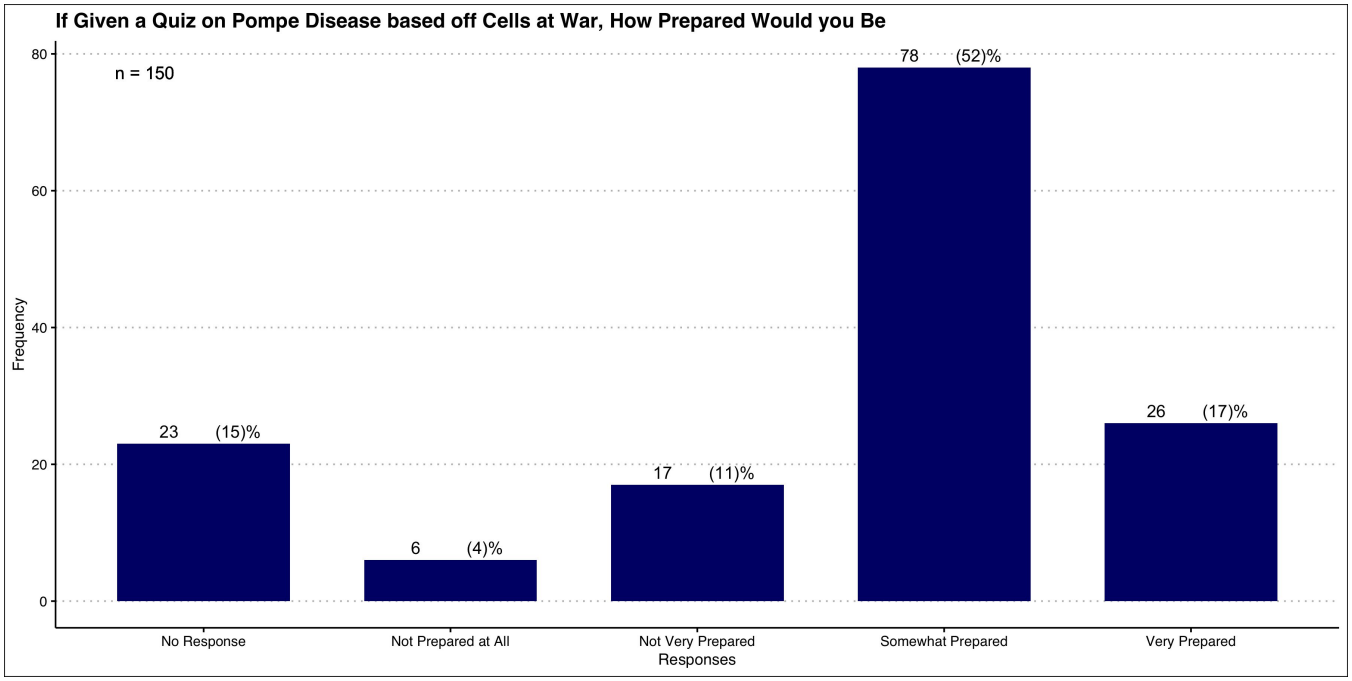


Figure 8: Student responses regarding how prepared they would feel if given a quiz on Pompe Disease based off Cells at War compared to studying off traditional lecture slides

# Discussion

This project has developed an educational video game focused on a single gene disease, which presents students with important cellular and molecular biology concepts in an engaging and interactive manner. Through this study, we have found a way to enhance the delivery of lecture material with an interactive video game, and examined the impact of game-based learning on student motivation and engagement. This study also highlights the immense benefits both students and faculty gain when engaging in a collaborative and interdisciplinary work-integrated learning experience.

## Student benefits of game-based learning

Video games have been around for over 30 years, however, the rate at which technology is evolving has allowed video games to change from short, frenetic, and repetitive forms of engagement, to long, descriptive narratives and story lines (Annetta 2008). Although the results of this study lack quantitative data to support the use of video games in University classrooms, the qualitative feedback provided by students emphasizes the massive potential game-based learning interventions could have at the post-secondary level. O'Dowd and Aguilar-Roca (2009) report that static images used in lecture slides are not seemingly effective in conveying dynamic aspects of biological processes. The results from our study provide evidence for this as 69% of students reported being either somewhat or very prepared if they were to be tested on material using the video game to study, as opposed to studying off of traditional lecture slides. This highlights the need to shift from old fashioned, didactic educational practices, to newer methods that focus on keeping students engaged with the material being presented.

It has also been found that creating a more learner-centered environment in a large introductory biology course by replacing certain material with active learning exercises, can potentially increase engagement, promote critical thinking, and improve student attitudes (Moravec et al. 2010; O'Dowd and Aguilar-Roca 2009). Students were asked to report how game based learning interventions could help with following four things; combining ideas from different courses when completing assignments, connecting learning to societal/health related issues, connecting ideas from courses to prior experiences and knowledge, and learning something that changes understanding of a concept. The survey results show an overall increase in the number of students who responded "very much" in all four of these categories, compared to when they were asked how much they were currently doing these things without game-based learning. Video-games have the potential to be powerful educational tools that allow students to connect what they learn through engaging game dynamics, to other aspects of their lives.

It is also interesting to note that the survey results indicated that 41% of students felt that their coursework emphasized memorizing course material "very much". When asked how a game-based learning intervention could improve motivation to memorize course material, the results show a 14% decrease in the number of students who responded "very much". This highlights the ability video games have to promote understanding through play, rather than memorization of static textbook and lecture content.

## Benefits of the game-design process for educators and students

The Cells at War project was rooted in an interdisciplinary approach in which biology students, artists, programmers and game designers came together to share their expertise in their related fields. This approach benefited students in many ways, one of which was having students move from a more teacher centred approach to learning, to an instructional approach in which the students and educators co-create and co-learn together across a variety of disciplines. Benjamin Franklin's old adage of "Tell me and I forget, teach me and I may remember, involve me and I learn" seems to have some merit as what the project served was to foster a learning environment in which students become empowered, engaged and self-motivated when working and learning alongside their teachers. Universities are typically structured in discipline-centred silos, which encourage discipline specific research. Many benefits arise however when individuals from a variety of disciplines come together (Snow et al. 2010; Martin et al. 2020). Interdisciplinary teams are effective when they address complex, real-life problems and incorporate different perspectives (Beers et al. 2006; Choi and Pak 2007; Fischer and Ostwald 2005; Massey et al. 2006; Martin et al. 2020). Further, interdisciplinary projects encourage face-to-face interactions, develop a shared understanding of the problems they are attempting to address, and achieve effective team dynamics by building trusting, open environments that are not based on hierarchy (Stokols et al. 2005; Fischer and Ostwald 2005; Bruusgaard et al. 2010; Martin et al. 2020). Cells at War is a game based learning project in which students engage in experiential learning. Students working in interdisciplinary settings are reported to benefit from experiential learning as this leads to critical self-reflection, the development of transferable skills, and contributes to new ideas (Gemmel and Clayton 2009; Martin et al. 2020). Students at McMaster University and George Brown College were involved in a symbiotic process in which educators and students with different perspectives, abilities, and ideas were able to combine and apply their strengths and diverse knowledge and skills to build an educational video game that served as an engaging learning tool.

Aside from the benefits of engaging in an interdisciplinary approach, Cells at War is a highly engaging instructional tool developed by students, for students. The success of the development of the video game rests in educators and students working together in the game design process. This collaborative approach reaps mutual benefits and rewards. There has been a rising interest in the realm of higher education about "students as partners" and co-created learning and teaching (Felten et al. 2014; Dunne 2016; Mercer-Mapstone et al. 2017; Bovill 2020). As pedagogy in higher education has evolved, co-creation of learning has created more inclusive classrooms where students are able to build positive relationships with teachers, and students with students (Bovill 2020). As the McMaster and George Brown team engaged in the development process of the video game, what emerged was a strong student voice in which students had a say in what they were learning and how to approach it. The dialogue that emerged and the exchange of ideas not only served to create an innovative instructional tool but, reinforced and consolidated the many skills and concepts that students from each discipline were required to learn. Greater student-teacher interaction leads to students' academic success, good academic performance, higher educational aspirations, personal and intellectual development, student satisfaction, and enhanced motivation (Bovill 2020).

The benefits to students engaging in the learning process are many. Of equal importance is the benefit for educators engaged in this process. Using novel approaches to improve student learning is an ongoing consideration for all educators. The process in which Cells at War was developed, provided teachers with an alternate way to engage and motivate students through best practices. In addition, teachers were able to provide feedback to students, which also supported them in informing their next point of instruction.

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