

## **User Testing for Serious Game Design: Improving the Player Experience**

Contributors: Ross Shaw, Isabelle Sperano, Robert Andruchow & Dana Cobzas

Pub. Date: 2022

Product: SAGE Research Methods Cases

Methods: Recruiting participants, Case study research, Online surveys

Disciplines: Communication and Media Studies

Access Date: April 7, 2022

Academic Level: Introductory Undergraduate

Publishing Company: SAGE Publications, Ltd.

City: London

Online ISBN: 9781529605402

DOI: <https://dx.doi.org/10.4135/9781529605402>

© 2022 SAGE Publications, Ltd. All Rights Reserved.

This PDF has been generated from SAGE Research Methods Cases.

## Abstract

This case study reflects on our use of user testing during a research project in which we designed a serious video game, “Life on the Edge.” The target audience of the game is first-year post-secondary biology students. As we designed the game, user testing was a critical component that allowed us to identify issues. Any issues that interfere with the flow or enjoyment of a video game can be distracting to players. In what follows, we will describe the research design and discuss the processes for testing a serious video game that will allow you to identify game issues successfully. How you recruit participants, test players, and prioritize player feedback is a component of effective user testing and improving your game. With user testing, we were able to identify problems in the game, prioritize them, and address them. By using variable user testing methods, you can adapt to the changing needs of your game project and develop a successful serious video game.

## Learning Outcomes

By the end of this case study, students should be able to:

- Design and develop user testing for a serious video game
- Appraise user feedback in determining game design
- Identify strengths and weaknesses of user testing

## Project Overview and Context

This case study focuses on our use of user testing during a research project in which we designed and developed a serious video game called “Life on the Edge.” In 1970, Abt first defined the term serious game. According to him, “these games have an explicit and carefully thought-out educational purpose and are not intended to be played primarily for amusement.” The whole research project was conceptualized to help address a disparity in serious game development in the biological sciences at the post-secondary education level in comparison to the k-12 level. This may be due in part to the fact that serious games, where education is the primary goal of the game, are not necessarily fun to play (Buday et al., 2012) and Jones (2003) noted that post-secondary students do use video games as a method to avoid studying rather than as a tool to help in learning.

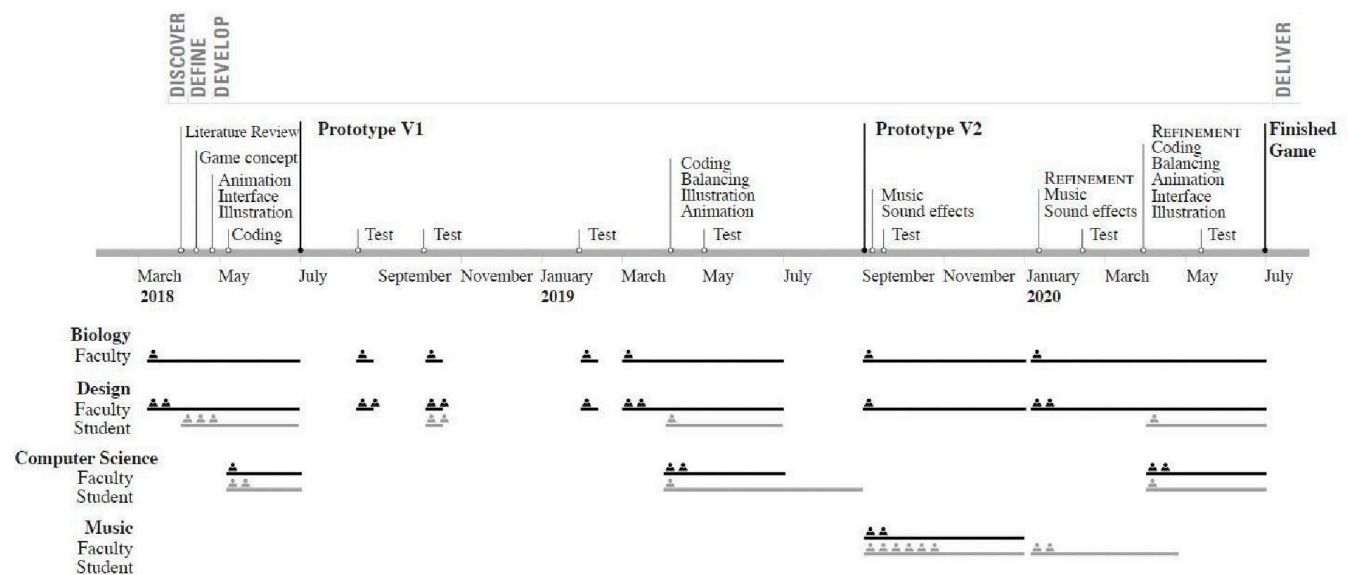
In order to design a game effectively (or any digital product), it is necessary to test the game with real users at several different stages in the game’s development to improve the player experience. The process of user testing allows you to identify specific issues or problems with the goal of fixing them. The quality of usability is defined by the multiple components of learnability, efficiency, memorability, errors, and satisfaction when users encounter a product like our serious video game. User testing should be conducted continuously in the design process, so we chose to do it throughout the project, even at the very beginning in the design


process. Because the development of the product would be very advanced, as mentioned by Hall (2019, p. 107), leaving testing until later in development could lead to very expensive changes and reveal problems that might be too difficult to fix at an advanced stage of a project.

In this project, we developed a serious video game for first-year university students in biological sciences. The game is a tower defense type game: a strategy game where players defend a structure or territories against enemies by setting up defensive structures. In our game, Life on the Edge (LOTE), players defend a cell against enemies (bacteria and viruses), changing environments (water and nutrients), and learn about key biological functions of a cell (learning outcomes of introductory cell biology). The main goal of LOTE is to teach key learning outcomes of introductory cell biology to students as an alternative educational resource or to supplement traditional educational resources (i.e., biology textbooks, videos, animations, etc.). Key learning outcomes for cell biology addressed by the game are how the structure of cell components relates to their function and recognizing how the flow of energy and homeostasis underlies all cellular processes.

During the process of development of our video game, we conducted user testing at multiple stages: the first prototype version 1 (2018–2019) and prototype version 2 (2019–2021). Prototype version 1 had basic gameplay features, a tutorial, and the first two levels. Prototype version 2 received a redesigned graphical user interface, an additional 3 levels, and full music and sound (Figure 1). For each of these stages, we conducted user tests on either students or instructors (faculty members) who represented our target audience for the game as an educational resource. The project heavily incorporated input and feedback from students.

**Figure 1. Development timeline, Life on the Edge.**



Note: Each symbol  represents one participant from a specific discipline at a particular stage of the project.

Source: Reproduced from Sperano et al. (2021).

The game was tested on multiple occasions to improve the game using a combination of informal and formal testing (Lallemand & Gronier, 2006) (Table 1). Informal feedback allowed us to determine if our game concept

overall was accepted by students and faculty or we were “headed down the correct path.” Formal tests provided an opportunity to improve the game and measure the overall user experience of players and how they learned things during gameplay. Formal testing used a think aloud protocol, which is typically used when designing digital products. As (Galitz, 2007, p. 819) stated “In a think-aloud evaluation, users perform specific tasks while thinking out loud. The objective is to get the user to talk continuously. All comments are recorded so all thoughts are captured, and subtle points are not missed when analysis occurs.”

**Table 1. Game assessment details**

Date	Game prototype and context	Users	Number of participants <sup>a</sup>	Type of test
August 2018	Prototype V1: Personal Locations	Friends and family	5	Informal
October 2018	Prototype V1: At MacEwan University	MacEwan undergraduate students	5	Formal
October 2018	Prototype V1: At MacEwan after a presentation at MacEwan Office of Teaching and Learning Services	MacEwan faculty from various disciplines	15	Informal
February 2019	Prototype V1: At MacEwan after a presentation at MacEwan Celebration of Teaching and Learning	MacEwan faculty from various disciplines	10	Informal
May 2019	Prototype V1: At MacEwan after a presentation at Annual Meeting of the Undergraduate Biology Educators of Alberta	Undergraduate biological sciences professors in Alberta	32	Informal
	Prototype V1: At Dark Matters Game on Telus World of Science public event	General public	16	Informal
August 2019	Prototype V1: At MacEwan University with 1 Facilitator	MacEwan undergraduate students and faculty in biological sciences	7	Formal
November 2019	Prototype V2: At a Biology Leadership forum, Pearson Education, Canada	Various biological sciences faculty	20	Informal
February 2020	Prototype V2: At a Editorial Advisory Board Meeting, Nelson Education, Canada	Various biological sciences faculty	21	Informal
June	Prototype V2: At virtual interviews with participants	Biological sciences students	10	Formal

Date	Game prototype and context	Users	Number of participants <sup>a</sup>	Type of test
2020				
October 2020	Prototype V2: At anonymous online game and questionnaire access	Biological sciences students	19	Formal
July 2021	Final: Bug testing and play balancing	Research assistants in biological sciences and computer science	2	Formal <sup>b</sup>

<sup>a</sup>Number of participants are estimated based on enrollment for informal testing sessions.

<sup>b</sup>Formal testing focused on bug testing and play balancing.

## Section Summary

- This case study is based on [Sperano et al. \(2021\)](#).
- Key goals of this project were to develop a serious video game for first-year biology students that both teaches and is fun to play.
- The project relied heavily on student input across multiple disciplines.
- Informal and formal testing were used many times in the game development.

## Research Design

### Practice Based Research

We decided to use practice-based research or “research that takes the nature of the practice as its central focus” ([Candy, 2006](#)) in designing and testing LOTE. Video games lend themselves to this approach as they are played in real-world complex social situations. Video games, in general, are well known to post-secondary students, and exposure to serious video games begins as early as preschool to kindergarten in our educational system. To design, build, and test a serious video game, we required multiple disciplines to be involved in the project. Students and faculty across multiple applied disciplines, namely, biological, computing science, design, and music, were able to use their skills and gain professional experience during design, building, and testing of the game.

### Design of LOTE

As described by Isabelle [Sperano et al. \(2021\)](#), a double diamond design process was followed, in which the creation process is divided into discover, design, develop, and deliver. Knowing the steps of design, you will use helps you decide the context of your testing.

## Timeline

A timeline had to be developed for the game (Figure 1). Since this was the first video game anyone on the team had developed, we determined it was best to build a smaller game that would only take players several hours to complete. To secure proper funding, faculty, and student support, the project timeline was 3 years from start to finish. A serious game that players could complete in only a few hours was more likely to keep players engaged and learning than a long and challenging game. Post-secondary students often enroll in 2 to 4-year programs at MacEwan University, where the game was developed and tested.

## User Testing of LOTE

A prototype version 1 (PV1) of the game was developed and then tested as the first playable stage of the game. A research ethics application was approved for testing, allowing us to recruit testers and apply a think aloud protocol during interviews. Our goals were to determine if students and instructors understood and enjoyed the metaphor of a tower defense game for this type of content and to spot major interaction issues.

We conducted both formal and informal testing sessions (Table 1) (Lallemant & Gronier, 2006).

## Formal User Testing

Formal testing sessions were between 30 min and 1 h. In the formal sessions conducted in October 2018, participants were invited to play the game in a dedicated room with one facilitator and two observers. A facilitator is someone who presented the scenarios and tasks we were testing. This facilitator should be personable and patient with an approach that uses a balance of sociability and self-awareness as they can have significant negative impacts on the testing, which you want to avoid (Hall, 2019). Our facilitator was Dr Isabelle Sperano, a faculty member in design studies for PV1. Observers (student research assistants) were present to take notes on the severity and frequency of problems, so the facilitator could focus on the participant.

The game was displayed both on the computer and on the monitor behind participants so observers could witness their behaviors and stay at a distance to avoid distracting them (Figure 2). Participants were recruited only once, as we wanted accurate feedback on how players would play the game for the first time. For early PV1 testing, a small number ( $n = 5$ ) of biology students were recruited as participants. It is important to select testing participants who share key goals with the game's target audience. Students were asked to play the game and give comments out loud while observers were taking notes on nonverbal frustrations or emotions, verbatim quotes, and any main problems encountered with the game (Galitz, 2007; Hall, 2019). The think aloud protocol requires the user to talk continuously while comments are recorded without missing subtle points.

### Figure 2. Physical setting for the formal testing sessions.



Source: Reproduced from [Sperano et al. \(2021\)](#).

We created an inventory of issues and then grouped them into larger problem categories. From this, we identified trends and larger issues to fix. At this stage, it was important to understand the larger conceptual and game play issues (e.g., not enough guidance, warnings too subtle, not well balanced, etc.). Fixing large issues would fix the smaller user issues identified.

We also used a questionnaire on user experience, gameplay, and learning to address our goal of balancing fun and play. The questionnaire used an adaptation of AttrakDiff Short scale ([Szwillus & Ziegler, 2003](#)) to assess the game's overall user experience. The test instrument uses opposing adjectives rated on a 5-step scale (1 = very negative, 2 = negative, 3 = neutral, 4 = positive, 5 = very positive).

The context of formal user testing was modified as the project progressed ([Table 1](#)).

### **Informal User Testing**

Informal user testing sessions were between 15 and 30 min. Most informal sessions took place after conference presentations. These sessions were informal as audience participants were simply invited to try the game if they wished. General comments and feedback were solicited and noted. They used a supplied USB or laptops previously setup at a table. The primary investigator circulated among audience participants to troubleshoot and orient players on how to start the game.

## Formal Testing Prototype Version 2

A prototype version 2 (PV2) version of the game was produced with a significant overhaul to the graphics user interface, and coding of the game to implement major features such as game saves and level structure. A research ethics application was completed for PV2 testing, approved, and anonymous test subjects were recruited. We formally tested this PV2 on students (Table 1). Formal testing interviews were moved to a virtual environment for June 2020 due to pandemic health restrictions. To observe participants playing the game virtually, screen sharing was enabled in Google Meet sessions. For these virtual sessions, we used a research assistant as the facilitator and Dr. Isabelle Sperano as the observer. The research assistant was required to complete additional research ethics training. This was essential in helping students participating in the project feel that participation was voluntary, as the students were recruited from course sections the primary investigator taught.

In October 2020, we ran a completely anonymous online testing of the game recruiting online sections of Biology 107 (Introduction to Cellular Biology) and Biology 101 (Current Issues in Human Biology) to participate. These courses represent our target audience as the game teaches content of both. Test subjects were given access to an online link to the game, and after playing LOTE, they were requested to complete a similar questionnaire to the PV1 questionnaire. Follow up reminders announcements via emails and postings were sent to enroll in the project, play the game, and complete the questionnaire. Again, our team evaluated the feedback, prioritized feedback, and implemented feedback into the game design using the methods described earlier.

## Finished Game

A final version of the game was created after further focused playtesting and quality assurance testing or “bug testing.” Bug testing involved testing by two students, one in biological sciences and one in computer science, who were hired as research assistants to play the game repeatedly. These two students evaluated the game for errors and play balancing and worked closely with the programmers of the game.

## Section Summary

- Practice-based research in design and testing of a serious video game allows participants to gain skills and professional experience. This research was student-based, with students designing and testing the game.
- The project used the double diamond design process of discover, define, design, and deliver.
- For testing, we recruited participants to test the game formally and informally during two major prototypes (versions 1 and 2). Formal involved structured interviews and the completion of a questionnaire, while informal focused on feedback gathered from conference audience members who play tested the game.
- When recruiting student participants from the primary investigators sections, it was important to use a student research assistant as an intermediary in communication to remove any undue pressure to



participate those students might feel.

- Feedback was implemented based on ranking of comments received. Rank was determined by focusing on the larger conceptual and game play issues, which when solved, addressed many smaller user issues.

## Research Practicalities

This serious video game project involved students to test the various versions of the game (PV1 and PV2). Therefore, a research ethics application needed to be completed and approved first by our ethics board.

When the ethics' application was approved, we recruited students. To do so, an initial email was sent to students enrolled in class sections at MacEwan University of Introduction to Cellular Biology (Biol 107) and Current Issues in Human Biology (Biol 101).

Various ethical components were included in our process. For example, to ensure participation was voluntary and anonymous, identifying information of participants was not recorded during interviews or in questionnaires. If identifying information was entered or voiced by participants, it was removed or not recorded by co-investigators involved in the project. Also, in order to avoid undue influence of the primary investigator on recruiting student participants he taught, a co-investigator and research assistant conducted interviews and communicated with the student participants.

As game development progressed a wider pool of participants was recruited to further validate feedback.

### Section Summary

- Research with human participants requires research ethics approval. It is important to allocate time to write and modify research ethics applications.
- To ensure voluntary and anonymous participation, direct work with participants can include co-investigators and research assistants. These researchers may need to complete additional ethics courses.
- If gathering formal or informal feedback, it is important to allow participants adequate time to play the game.

## Method in Action

Our project developed a serious video game, LOTE, that, based on user feedback is fun to play ([Sperano et al., 2021](#)). Although the game is a serious game with a primary goal of teaching learning outcomes, it was also a goal of the project to address a call by the serious game academic field to produce educational games that are also fun for players. Students generally experience high exposure to educational games before university and are more aware of what they might find “fun” than older generations (academics) who might teach them. An ideal serious video game would provide both learning and fun. A key component to our success was to

rely on students in developing the game providing valuable feedback from our target audience.

## Extensive Time Required

Although rewarding, development of a video game can be exhaustive and require thousands of team effort hours even on a small game such as LOTE. The development phase was the longest (Figure 1). Prototype V2 testing introduced further issues that in turn required more programming hours than we originally planned for. However, working with a skilled interdisciplinary team is rewarding and will give you a chance to improve your communication skills.

## User Testing of LOTE

In envisioning a serious video game and testing of PV1 and PV2, we assumed students would be quite interested in the project. In reality, more students and faculty were interested in just playing the game than providing constructive feedback on its design. This is understandable, as a fun to play serious video game is more engaging than filling out a questionnaire for research purposes.

## Formal Prototype Testing

We required only a small number (less than 10) students to test the PV1 and only received responses from a small number ( $n = 6$ ). This is not unexpected and, in the early stages of design, it is a common practice when testing prototype concepts on a target audience (Budi, 2021). Although more participants were recruited, we still dealt with “no-shows” that had scheduled interviews.

For testing prototypes of the game, face-to-face interviews worked well. Allowing a research assistant to facilitate interviews worked well as long as an experienced observer was present. These sessions provide an opportunity for students to get experience in user testing. Think aloud protocols had the advantages of using actual in-game tasks and helping users focus and concentrate on these tasks.

Participants gave us valuable, detailed feedback into their reasoning, and allowed us to identify problems with the game and rank them. We were able to fix all the major problems. Some game problems were overlooked or given initial low priority. However, watching actual players struggle with components of the game convinced us to address these problems. Think aloud protocols could have some limitations as participants can get distracted or slowed by the process of verbalizing and can find the process exhausting. This did not seem to be an issue during our testing sessions.

Virtual interviews necessitated by COVID-19 health restrictions had limitations. For example, the observer was unable to see the nuances of non-verbal or emotional responses as screen sharing showed us the players' gameplay, but not their expressions.

Prototype V2 testing attempted to recruit participants from a large pool (over 380 students) of biology students. Approximately 75 students accessed the game; however, only 19 students completed our questionnaire on LOTE. Our expectations might have been unrealistic for achieving high numbers of

questionnaire completion as it was administered anonymously online. During this time, the pandemic may have also contributed to students being overwhelmed and “burnt out” thus not completing the research questions. In future, testing a game outside of a pandemic or in a face-to-face classroom session would improve participation as students are prompted in class and given time to complete the survey. Alternatively, the game testing and questionnaire could be presented in the context of an assignment, motivating students to complete it.

## Informal Prototype Testing

Using conferences to test the game worked well for providing us access to high numbers of faculty ([Table 1](#)). A drawback to this approach is that little time is available to allow players to play the game. Conferences typically assign a maximum of 30 min in which we have to present the game, have players play it, and gather informal feedback. Players tended to be highly engaged playing the game and used all time available to do this after our presentation versus providing feedback.

## Section Summary

- Our goal to create a serious video game that both teaches and is fun to play was achieved by relying on student input during development and testing.
- Our project timeline took many more hours than initially envisioned. Issues in game play mechanics and programming needed to be addressed throughout the project.
- Expectations from both recruitment and feedback of prototype testers were higher than what we received. Formal one-on-one interviews guided by research assistants worked well for playtesting LOTE and completing questionnaires. Online anonymous surveys were not completed in high numbers.
- Informal feedback was useful in validating our general concepts of the serious video game but did not provide enough time to complete participants’ playtesting or providing much feedback.

## Practical Lessons Learned

### Research Ethics

Recruitment of participants required a detailed research ethics application and completion of an online course in research ethics by all researchers. Plan ahead and build in sufficient time to your project to write and modify ethics applications, they may take more time than the research itself! Ethically our methods had to clearly identify how we would ensure participation was voluntary and would remain anonymous. As a primary investigator in research, you want to encourage participation in your research projects yet not put any pressure on possible participants. Using a co-investigator or a student research assistant to facilitate recruitment acts as a buffer between you and the participants and protects their anonymity. Before reviewing the data as the primary investigator, ensure that any identifying information is stripped from the results.

## Variable Testing and Sufficient Numbers

As with most research projects, methods undergo revision based on results obtained. Serious video game development is no different and game development benefited from both formal and informal testing sessions using different methods. Allowing flexibility in how you test your users and testing throughout your project can allow you to adapt to the needs of the project.

We sought feedback from our target audiences: faculty and students of Biol 107 and Biol 101. Selecting a large enough cohort of audience members helped us address general variability in participants, in particular if they had ever played video games. It is important to not only address the correct audience for user testing but also achieve sufficient numbers. Forty seven percent of students in PV2 testing reported they played video games daily or at least weekly. All participants reported playing LOTE for less than 2 h, which is what we designed the game playtime to be. This feedback consistently identified that the game was fun to play and helped students understand how different cell structures work in the context of a video game. During testing, anonymity was ensured by accessing our online game and questionnaire via a web link. However, the number of participants was on the lower end, and even less of them completed the questionnaire. It is important in user testing to offer an incentive to complete parts of your testing that may not be motivating to your participants. Do not rely on the engaging and interesting aspects of your research project to be enough to elicit sufficient participants.

## Evaluating User Feedback

Setting up formal, scheduled interviews for user testing with a facilitator and observer provides several advantages. If you have a skilled facilitator who can make the participants feel welcome and orient them through the process, most participants were unfamiliar with the think aloud protocol, and it was important to explain how the process worked before proceeding with the testing. Any concerns or uncertainty in participants on how the session would work had to be addressed so it did not confound the results we were observing. As a facilitator you need to avoid guiding participants in how to play the game and to not help them when they get lost. It is also important to let them fail and identify problems you may not have thought of or acknowledged by how severe and frequently they occur. Participant's playtesting a video game can become very emotional and often blame themselves for errors or difficulty they have with the game. When we encountered this, we asked participants to identify what they expected to happen and why. It is important observers both free up the facilitator and do not distract the testers with comments or by sitting too closely to them, and take detailed notes or audio record the session. Our observers took notes on the participants' verbal comments, tasks they failed, and emotions. Once you have created an inventory of issues grouped into larger categories, address the recurring larger issues. Fixing these will also fix many smaller user issues.

## A Sample of User Testing Results

Our formal feedback on the PV1 form of the game, which had a tutorial and two levels, was very informative. We discovered that players gave input on: LOTE guidance (more step-by-step needed); interactions (interface

is too subtle); levels (too long), rewards (stagger unlocking of components by level); and warnings (too subtle). Using this feedback, we overhauled the game interface and level design to produce PV2. A new interface and level design addressed the majority of play testers' prototype feedback and the user experience improved (Sperano et al., 2021). Constructive feedback improved the gameplay by helping us narrow down timing (too fast versus too slow) and providing multiple visual and auditory cues to the player during stressful cell events (i.e., cell membrane damage or cell death is "near"). For example, players repeatedly commented they would like "more of a warning" when their cell was at risk for dying. Indeed, during the tests, players just ran out of energy (ATP) and died, which was unacceptable and puzzling to most. Overall, players experienced a quality "user experience" even when playing the PV2 of the game.

## Face-to-Face Versus Virtual User Testing

We had originally planned to do face-to-face interviews during PV2 testing, however, the COVID-19 health restrictions did not permit this. To adjust to these requirements, we moved to virtual or online sessions. Although we met participants using video conferencing, a virtual session is not as good as a face-to-face interview. Reading nuances of emotions and other facial expressions is not as easily done in a virtual session. This is an important part of interpreting players' reactions to a game, and you should include a setup that allows you to observe the emotions of the participants.

## Section Summary

- Ethics applications are required for user testing and may require modification as methods change.
- Variable user testing methodology can benefit a research project by allowing you to adapt to the needs of the project.
- User feedback will differ based on the stage of video game development, yet the same criteria can be used in selecting which feedback to implement.

## Conclusions

The study described here demonstrates that user testing of a serious video game can occur throughout the development process. Arguably, it is quite beneficial to be able to adapt your user testing as your game changes and you attempt to recruit more participants to validate your design decisions. A small number of participants is adequate to give you initial feedback on an early prototype, and both formal and informal testing can be used.

Formal testing using a think aloud protocol with carefully chosen facilitators and observers, each with defined roles, will identify issues with your game that users encounter. Accurate recording and ranking of the issues will help you identify which problems to solve, thus improving your players experience. Solving large issues upfront will also solve many small problems perceived by game players. As researchers in a project, you may overlook or underestimate barriers your users might encounter. Formal testing will convince you.

Informal testing also provides access to a wider audience to further validate your general game ideas and playability without having to guide participants as much through playing your game.

Having flexibility in your testing methods and adapting them as your game evolves will allow you to tackle problems that arise. Ensuring anonymity and confidentiality of your participants is important in research ethics, but true anonymity may result in low participation without further incentives.

## Section Summary

- User testing throughout a project can address different issues as the project evolves. Using a mixed-method approach of formal and informal sessions will provide user feedback to rank and solve problems in game design.
- Selecting skilled facilitators and observers for testing sessions helps gather useful feedback identifying problems to solve in your game design.

## Classroom Discussion Questions

1. If you were interested in identifying problems with your video game design, how would you plan your testing? What tasks would you give your players? How would you rank problems you discover? What type of video game would you choose for participants to play?
2. During the design of your video game your team has an extended debate over what interfaces to use for the game (i.e., virtual reality goggles, mouse, keyboard) and cannot come to a consensus. What might you do to resolve this debate and convince the team to agree on a solution?
3. In planning formal testing sessions how do you ensure participant anonymity? If your recruitment decreases, how might you increase recruitment with incentives? What incentives are ethical?
4. When planning user testing of a videogame, when would you do formal testing? Informal testing? Why would you choose an approach over the other?

## Further Reading

**Galitz, W. O.** (2007). *The essential guide to user interface design: An introduction to GUI design principles and techniques* (3rd ed.). Wiley.

**Hall, E.** (2019). *Just enough research* (2nd ed.). A Book Apart.

**Sperano, I., Shaw, R., Andruchow, R., Cobzas, D., Efirid, C., Brookwell, B., & Deng, W.** (2021). Creative interdisciplinary undergraduate research: An educational cell biology video game designed by students for students. *Scholarship and Practice of Undergraduate Research*4(2), 5–14. 10.18833/spur/4/2/7

## Web Resources

<https://lifeontheedgegame.com/>. (This is the website of the game Life on the Edge, a serious video game

developed to teach concepts to first year post-secondary biology students).

[https://ethics.gc.ca/eng/tcps2-eptc2\\_2018\\_chapter3-chapitre3.html](https://ethics.gc.ca/eng/tcps2-eptc2_2018_chapter3-chapitre3.html) (Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans – TCPS 2 (2018). This website reviews current Canadian policy for ethical research involving humans).

## References

**Abt, C.** (1975). *Serious games*. 176 pg. 10.1177/000276427001400113

**Buday, R., Baranowski, T., & Thompson, D.** (2012). Fun and games and boredom. *Games for Health Journal*, 1(4), 257–261. 10.1089/g4h.2012.0026

**Budiu, R.** (2021, July11). *Why 5 participants are okay in a qualitative study, but not in a quantitative one*. Ngroup. <https://www.nngroup.com/articles/5-test-users-qual-quant>

**Candy, L.** (2006). *Practice-based research: A guide*. CCS Report 2006–V1.0 November.

**Galitz, W.** (2007). *The essential guide to user interface design: An introduction to GUI design principles and techniques* (3rd ed.). Wiley.

**Hall, E.** (2019). *Just enough research* (2nd ed.). A Book Apart.

**Jones, S.** (2003, July6). *Let the games begin. Gaming technology and entertainment among college students*. <https://www.pewresearch.org/internet/2003/07/06/let-the-games-begin-gaming-technology-and-college-students/#gaming-technology-and-entertainment-among-college-students>

**Lallemand, C., & Gronier, G.** (2006). *Méthodes de design UX: 30 Méthodes fondamentales pour concevoir et évaluer les systèmes interactifs*. Eyrolles.

**Sperano, I., Shaw, R., Andruchow, R., Cobzas, D., Efird, C., Brookwell, B., & Deng, W.** (2021). Creative, interdisciplinary undergraduate research: An educational cell biology video game designed by students for students. *Scholarship and Practice of Undergraduate Research*, 4(2), 5–14. 10.18833/spur/4/2/7

**Szwillus, G., & Ziegler, J.** (2003). Mensch & Computer 2003. In *Berichte des German Chapter of the ACM* (Vol. 57, pp. 187–196). Vieweg+Teubner Verlag. 10.1007/978-3-322-80058-9