Check for updates

Computer Graphics and Extended Reality Courses for the Programmophobic

Stefan Marks
Sebastián Gil Parga
stefan.marks.ac@gmail.com
s.gilparga@gmail.com
Auckland University of Technology
Auckland, New Zealand

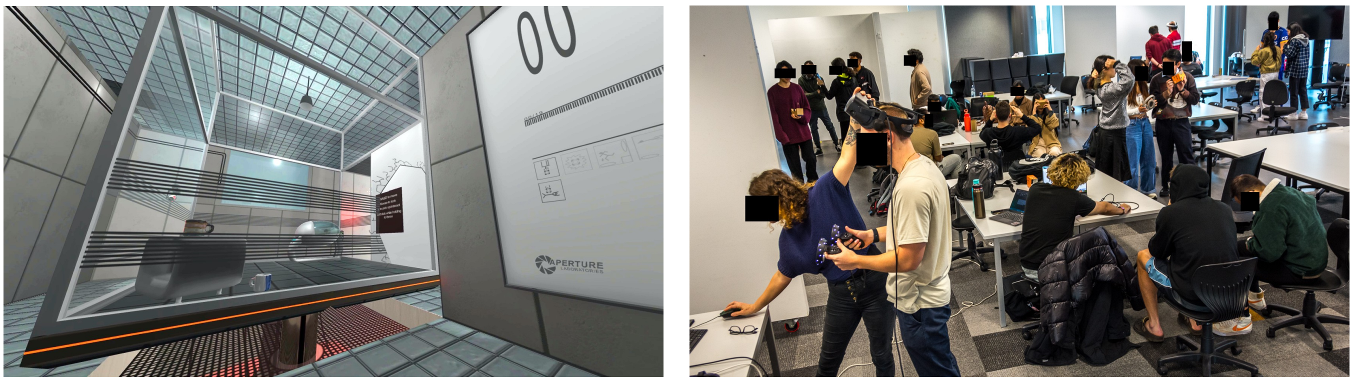

Figure 1: Screenshot of an example submission for the Computer Graphics course CTEC601 (left). Showcase day for the XR course COMP770 (right).

ABSTRACT

This paper describes the challenges and solutions to teaching computer graphics as well as extended reality concepts to students from a variety of backgrounds in the context of the School of Future Environments at the Auckland University of Technology, New Zealand. Examples are provided for the content and assessment strategies for two courses, as well as a summary of student work and feedback collected over the last three years.

CCS CONCEPTS

• **Applied computing** → **Education**; • **Computing methodologies** → **Computer graphics**; • **Human-centered computing** → **Virtual reality**; **Mixed / augmented reality**.

KEYWORDS

education, computer graphics, virtual reality, augmented reality

ACM Reference Format:
Stefan Marks and Sebastián Gil Parga. 2023. Computer Graphics and Extended Reality Courses for the Programmophobic. In *SIGGRAPH Asia 2023 Educator's Forum (SA Educators Forum '23), December 12–15, 2023, Sydney, NSW, Australia.* ACM, New York, NY, USA, 8 pages. https://doi.org/10.1145/3610540.3627004

Permission to make digital or hard copies of part or all of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for third-party components of this work must be honored. For all other uses, contact the owner/author(s).
SA Educators Forum '23, December 12–15, 2023, Sydney, NSW, Australia
© 2023 Copyright held by the owner/author(s).
ACM ISBN 979-8-4007-0311-9/23/12.
https://doi.org/10.1145/3610540.3627004

1 INTRODUCTION

Computer Graphics and Extended Reality (XR) technology has become ubiquitous, e.g., the former in form of special effects in movies and TV [Sawicki and Moody 2020], and the latter through companies such as Meta and Apple developing and distributing virtual- and mixed-reality headsets to the consumer market at more or less affordable prices [Brown 2023].

Specifically in the context of the school that both authors are a part of (see Section 2.1), it would be negligent not to offer courses that prepare the students with knowledge and hands-on experience of those topics. However, due to the large diversity of the students enrolled in the two courses discussed in this paper, challenges with respect to specialised hardware, as well as the breadth of the content to be taught, course materials and assessments must be carefully designed to tackle the numerous challenges and to provide a positive learning experience.

2 CONTEXT

2.1 Faculty and School

Auckland University of Technology (AUT) comprises five faculties, of which the Faculty of Design and Creative Technologies is the largest. This faculty in turn consists of four schools: the School of Art and Design, the School of Communication Studies, the School of Engineering, Computing and Mathematical Sciences, and the

School of Future Environments. The latter was established in 2020 and offers courses around architecture, built environments, and creative technologies.

2.2 Degrees and Courses

Both courses introduced in this paper have originated in the Bachelor of Creative Technologies (BCT). This degree is a wide-ranging mix of courses focusing on a breadth of skills that, according to industry feedback, make the graduates very flexible in their future workplaces. As an example, other courses taught in the context of the BCT programme are "Creative Technologies Studio", "Knowledge, Inquiry and Practice", "Physical Computing", "Creative Audio", "Digital Fabrication", "Entrepreneurship and Innovation", "Experimental Imagery", etc.

In alignment with the cross-disciplinary nature of the faculty and school, several of those courses are also offered as a Creative Technology Minor as elective courses to other students not only in the school and faculty, but effectively every student across AUT. This is one of the reasons why both courses specifically discussed in this paper do not list any prerequisite courses as part of their descriptors. While this simplifies enrolment for students from a diverse range of other schools and degrees, it also has obvious disadvantages with respect to the content that can be taught and prerequisite knowledge that can be expected, which is discussed in more detail in Section 3.3.

Both courses are "15-point" courses, translating to 150 hours of overall taught and self-directed study time, and thereby forming one fourth of a typical semester load of 60 points. A typical bachelor's degree at AUT requires 360 points over the course of three years.

2.3 CTEC601 - Synthetic Realities

This course is usually taken in the second year of the BCT. The course descriptor reads as follows:

Prescriptor. Emphasises mechanics of synthetic realities and virtual worlds, which may include animations or games. Concepts related to synthetic realities including but not limited to environmental design, interactive game design, experiential factors and non-linear storytelling will be covered.

Content. Students will use 3D modelling software, painting software, sound editing software, game engines and programming languages to develop synthetic realities in response to a project brief.

Learning Outcomes.

- LO1: Identify and explain underlying principles for visual and auditory aspects of synthetic realities.
- LO2: Identify and explain underlying principles for simulated and dynamic aspects of synthetic realities.
- LO3: Use appropriate digital technology to develop and exhibit a synthetic reality.
- LO4: Design and develop appropriate interaction mechanisms for a synthetic reality.

This descriptor is fairly flexible in how it can be interpreted, as historically, the courses in the BCT were not always taught by the same staff members with similar research interests and domain expertise. However, since about 2015, the main focus of this course crystallised around applied Computer Graphics in general, and how to create a synthetic version of reality in a mostly visual, but also auditory and experiential way.

2.4 COMP770 - Virtual and Immersive Environments

This course is usually taken in the third year of the BCT. The descriptor of this course reads as follows:

Prescriptor. Develops advanced practical and conceptual skills in the production of technology-facilitated environments that are simulated, virtual or augmented, immersive and interactive in nature. Covers the production and assembly of integrated technology and media assets into interactive environments. Identifies and evaluates a range of non-linear narrative and information structures. Critically evaluates notions of interactivity and the interface in relation to new media forms, in order to generate a range of technology-based strategies for simulation, interaction and human-environment interface design.

Content. Technologies for simulated, virtual and augmented realities; Human Perception; Interactivity and scripting; Asset creation, management, and integration (e.g., 3D models, spatial sound, stereoscopic/360 degree video); Storyboarding and concept mapping

Learning Outcomes.

- LO1: Apply and communicate basic interactive requirements (e.g., motivation, navigation, usability, functionality).
- LO2: Identify and discuss conceptual models of interactive design (e.g., perception, spatiality, narrative).
- LO3: Identify and account for ethical and cultural aspects and issues in virtual environments and applications.
- LO4: Create and integrate suitable assets (e.g., 3D models, spatial audio, stereoscopic and 360 degree video) to a functional virtual and immersive environment.

This course also underwent some transformations prior to 2015, and then "stabilised" around the concepts of XR. Before 2021, the focus was mostly on VR, but AR was added to the course material and assessment options after that.

3 CHALLENGES

3.1 Hardware

In both courses, providing the necessary hardware to develop and run authored 3D content is a challenge. AUT has several classrooms with suitable computing hardware, however, these are naturally in strong demand. In our school, however, students are encouraged to have their own laptop. In case students cannot afford one, the university provides some machines in class, as well as the opportunity to book computer lab machines. The performance range of the student laptops is broad, and for financial reasons, only a few students have high-end 3D capable machines. Therefore, any software used in class has to be easy to moderate on computing resources, e.g., by choosing Unity Engine over Unreal Engine (see Section 3.2).

For developing high-end content, students either use their resources at home, or they are able to work with two more powerful machines (HP EliteDesk 800 G6 Tower PC, 2.9GHz Intel i7-10700 8-core CPU, 32GB RAM, NVidia GeForce RTX 2060 8GB GPU) or two VR-capable laptops (Gigabyte Aero 14 and 15, Intel i7-7700 4-core / i7-8750 6-core CPU, 16GB RAM, NVidia GeForce GTX 1060 6GB GPU) on a time-share basis.

For COMP770, there is the additional problem of providing access to XR hardware. Prior to 2020, the school had four HTC Vive headsets [HTC Corporation 2023] and four HP Windows Mixed Reality Headsets [HP Development Company 2023], in conjunction with the two workstations mentioned above. These resources were heavily contested, however, due to relatively low enrolment numbers (around 20), and students working in groups, it was manageable. Still, student feedback consistently mentioned "lack of resources" as a major aspect for improvement (see Section 6).

In 2020, due to the necessity to teach this course remotely during the COVID-19 lockdowns, we took the opportunity to a) switch to a Flipped Classroom model (see Section 4.2) and b) change the hardware requirements to mobile phones and Google Cardboard as a VR platform. This had several advantages:

- Students could continue working on their projects from home as almost all of them had at least one device to their disposal.
- The Google Cardboard Software Development Kit (SDK) provides a preview and simulator mode that allows for development even if the student does not have a stereoscopic viewer.
- The constraints of phone hardware require a stronger focus on optimisation, e.g., low polygon count, mobile-suitable shader models, etc.
- The complexity of developing for a 3 Degrees-of-freedom (3DoF) headset with only one button as input is much lower than for a 6DoF headset with two 6DoF controllers and their respective controls.
- The process of grading assignments is simplified as there is only one kind of hardware involved.
- From the Google Cardboard platform, it is fairly straightforward to extend a project to higher-end hardware such as the Quest 2.

In case of students not having a suitable phone, or for students with iPhones that require a more complex development setup, we had several Android phones available for loan.

We acquired several Google Cardboard sets to provide them to students during the development phase. In addition, over time, several different kinds of those viewers were accumulated and added to the stock. Some of those viewers did not come with the QR Code that is necessary to calibrate the dimensions and lens characteristics for the VR application. In most cases, these QR codes can be found on numerous dedicated websites such as Hypergrid Business [2023]. In rare cases where even those databases would not provide a suitable code, we used the Cardboard Viewer Profile Generator [Google Inc. 2023b] to calibrate those viewers and generate a custom QR code to print onto the case.

Since the changes in the course were received well and had no significant negative effects on the student evaluations, we kept that delivery model and the hardware requirements in the following years. However, in 2021, we added a) the opportunity for student groups to "earn" better hardware, e.g., a Meta Quest 2 [Meta 2023] or a Microsoft HoloLens 1 [Microsoft 2021] for their projects by justifying the use of such hardware for their idea in their first assignment item, the project pitch (see Section 5.2), and b) more Augmented Reality content and resources to the curriculum to allow students to develop for this XR technology as well.

3.2 Software

Currently, the most frequent software choices for interactive 3D content authoring, according to Toftedahl and Engström [2019], are Unity Engine [Unity Technologies 2023b], Unreal Engine [Unity Technologies 2023b], and open-source engines such as Godot [Linietsky and Manzur 2023]. All three of those engines support the workflows needed for both courses. However, with respect to XR development in COMP770, Godot has less support and features compared to Unity and Unreal.

The biggest factor for choosing Unity Engine over Unreal Engine in our context is the varied nature of the computers that the students use to work on their projects (see Section 3.1). The Unreal Engine editor in itself is fairly resource-hungry and does not work well on a normal laptop. Unity Engine is less demanding in that respect, and was therefore chosen for the courses.

The choice of software for the production of the necessary assets, e.g., audio and image processing is left up to the students. Each AUT student has access to the Adobe Creative Cloud [Adobe 2023], but the use of open-source software (e.g., Blender [Blender Foundation 2023], Audacity [Muse Group and contributors 2023], GIMP [The GIMP Team 2023]) is also encouraged.

For COMP770, an additional choice was that of suitable XR frameworks. For VR, the actual hardware like headset, controllers, and other tracking devices is supported fairly well by the OpenXR standard [The Khronos Group Inc. 2023], which is in turn supported by Unity's XR Plugin Management [Unity Technologies 2023a]. On top of that, there are frameworks for higher level functionality such as interaction and navigation, e.g., Unity's own XR Interaction Toolkit [Unity Technologies 2023d], the SteamVR/OpenVR SDK [Valve Corporation 2015], and VRTK [Sysdia Solutions Ltd 2023]. Prior to OpenXR, the various SDKs for supporting a certain hardware made teaching and development in general challenging.

When we switched to Google Cardboard VR (GCVR), we adapted the existing SDK [Google Inc. 2023c] to run with the Unity framework, at first as a standalone software package, then later, when Google had made the SDK OpenSource [Peters 2019], as an XR plugin. Over time, though, when Google Cardboard was retired [Amadeo 2021], updates to that SDK ceased, and with more and more changes to Unity's XR framework, the GCVR broke in more and more places. Up to now (2023), we were able to fix those issues, but more and more advantages of the SDK started to disappear, such as the instant preview that allows for rapid development iterations.

For AR, Unity provides a similar layered framework. The AR Foundation Framework [Unity Technologies 2023c] plugin provides an abstraction of not only the two most widely used AR APIs, Apple's ARKit [Apple Inc. 2023] and Google's AR Core [Google Inc. 2023a], but also for hardware such as the MagicLeap and the HoloLens. This allows for relatively unified development regardless of the underlying hardware that students are using.

For the courses discussed in this paper, as well as for our research, we have created a growing library of Unity scripts that provide functionality for interaction and navigation [Marks 2023]. Initially, when development of this library started around 2013, it was driven by the scattered landscape of other APIs that were either not flexible enough or too cumbersome to use. As the framework has grown quite substantially over time, for the courses, the students are provided with suitable subsets of the full functionality (see Section 4).

3.3 Students

As mentioned in Section 2.2, both courses have no prerequisites so that they can attract students from across the faculty and even beyond. The majority of students from non-BCT degrees come from Computer Science and Engineering and, since 2021, also from Architecture as the courses are listed in programme information material under the Creative Technologies Minor.

Prior to structural changes in the school leading to the merger of Architecture, Built Engineering, and Creative Technologies (see Section 2.1), delivery of both of those courses could rely more on the high percentage of BCT students and the technical and programming knowledge gained in their first year of studies. Over time, with enrolments from a larger variety of degrees, this assumption had to be abandoned. The course content had to be changed so as to cater for a cohort that is not necessarily strong at coding. One major step was the provision of prefabricated code modules that could be put together like building blocks to form more complex behaviour without having to touch a single line of code (see Section 4).

4 COURSE CONTENT

With regards to delivery, in both courses, we record "contact time" and immediately upload those videos to the course pages, so students who are unable to attend in person or require reiteration of content can re-watch those recordings. In the student feedback (see Section 6), having this ability was always mentioned as a positive aspect of the courses. The equipment used for recording is one of the XR workstations (see Section 3.1) together with

- a Logitech C920 HD Pro webcam on a tripod with a ball head, connected via a 5m USB extension cable,
- Open Broadcaster Software (OBS) [OBS Studio Contributors 2023] configured to record the screen and/or the webcam plus audio into x264 encoded MKV files,
- a TP-Link Archer AX90 WiFi router for a dedicated streaming network, e.g., for wireless rendering to a Meta Quest headset, or for wireless transfer of the screen content of an AR application,
- a wireless USB microphone (Samson XPD2 Lavalier), and
- an LG-H930 mobile phone to a) demonstrate Google Cardboard and AR apps, and b) serve as a scene switch and recording-controller for OBS using *OBS-web* [van der Maas 2023].

This setup was also used during the COVID-19 lockdown periods for teaching from home, as well as for recording the Flipped Classroom lecture material.

4.1 CTEC601 - Synthetic Realities

The content of CTEC601 is mostly about the basics of 3D content creation: Principles of 3D coordinate systems, meshes, transformations, Physically Based Rendering, texturing, UV mapping, etc. It also covers spatial sound design, physical simulation, and optimisation mechanisms such as Level of Detail or performance monitoring. Event mechanisms such as input devices, collisions and triggers are covered, but, to avoid the dreaded "programming" scare, the students are provided with a subset of the Sentience Lab Unity Framework [Marks 2023] (see Section 3.2) and ample examples for how to "plug-and-play" those modules together to achieve simple to medium complex event mechanisms to create, e.g., puzzles, automatic doors, rockets, timers.

The course is delivered as an interactive face-to-face lecture that breaks into activities about every 20 minutes. Students are encouraged to work through the material in advance and ask any questions face-to-face or via email. Lectures dynamically adapt to those questions, and - if necessary - we add slide and tutorial content. One extreme example of this adaptation was the delivery in 2021 (during the COVID-19 Delta variant lockdown), where we completely walked through the creation of an example solution for Assignment 2, the recreation of the lecturer's kitchen, recording 5-10 minute tutorials for each step, and ending up with a 30 chapter tutorial playlist that is still used today.

Also, to make the connection between the courses and entice CTEC601 students to enrol in COMP770, demonstrations of XR applications are given at the end of the semester. Student submissions for Assignment 2 (see Section 5.1) are especially suitable to be demonstrated in a VR headset if they have been designed correctly with respect to scale and performance.

4.2 COMP770 - Virtual and Immersive Environments

The content for COMP770 covers aspects such as XR technology in general, principles of human perception, immersion and presence, interaction design, input and output, advanced spatial sound, and some more specific optimisation mechanisms especially for XR.

Since 2020, due to the first COVID-19 lockdown, this course is run using the Flipped Classroom model [Akçayır and Akçayır 2018; Ozdamli and Asiksoy 2016]. The course material is prerecorded, and students are expected to watch a content unit previous to that week's session. During class, the students are encouraged to ask questions and there is more time to work through the "highlights" and practical components of that unit. Students then have the opportunity to experiment with live examples of that unit's material, and to access specialised hardware such as 3D screens.

Especially during the phase in which students have to develop and implement their assessment outcome, class time is spent on providing examples in response to questions and issues. On several occasions, those questions have led to adding course material, slides, and additional software modules from the Sentience Lab Unity Framework [Marks 2023] (see Section 3.2). In some cases, software improvements and refactoring made especially for the course flowed back into the framework to be applied to our research projects.

Initially, the course was very VR-centric, but in 2022, we added more focus on AR and MR in the lecture material and examples, as well as allowing AR submissions for the assessment.

5 ASSESSMENT

Assessments for both courses are group-based with individual weighting. Students are encouraged to work in groups of two to four people, a) to reduce the amount of submissions and b) to encourage and foster collaboration as a soft-skill (see also Section 7). In order to adjust the marking to the individual contributions as well as to avoid fallout by group members not contributing or being sidelined, we also require submission of a document that details the development process and has a table with contribution percentages and individual signatures in it.

5.1 CTEC601 - Synthetic Realities

CTEC601 has two independent assessment items:

5.1.1 Assignment 1: A Rube Goldberg Machine. To demonstrate proficiency in the learning outcomes 2 and 3, the task is to build a Rube Goldberg Machine purely with physical simulation (no animation). The assignment builds on the content of the first 4 weeks which are the basics of coordinate systems and geometry, and rigid-body physics simulation. The focus is on simulated functionality and not on the visuals because 3D materials and texturing is taught after week 4. Additional focus is on a clear project structure, optimal configuration of physical elements, and the existence of an overarching purpose of the machine.

Student submissions ranged from simple domino chains up to complex mechanical clockworks driving a fully automated bowling alley. The marking scheme rewards a large variety of complex, well-timed mechanisms that also contain compensation measures for the simulation running at different framerates on differently powered computers.

5.1.2 Assignment 2: A Synthetic Reality. To demonstrate proficiency in all four learning outcomes, the task is to recreate an existing or fictional "place" from scratch. All geometry and materials have to be created from the ground up. No asset packages are allowed except for very basic ones and those provided in the course tutorials. With the course content being mostly about visuals and audio design, these are the areas that the marking criteria focus on. However, adding interactivity through the provided script modules and including some physically simulated elements is encouraged.

The limitation to "develop from scratch" is based a) on the nature of the course as an introduction to 3D creation principles and b) due to bad experience with students using asset packages or other resources that were unsuitable because of a high polygon count, weird object hierarchies or scale factors, or gigabytes of textures and models of which only a minority was used. Our philosophy is that understanding the basics by creating material from the ground up helps in better evaluating and selecting more complex and available resources later on.

Even with these restrictions, students have never ceased to surprise the teaching team with submissions of a broad range of complexity, such as:

- *The Enrichment Center* (Figure 1, left): A fully functional recreation of the first level of the computer game "Portal". Instead of taking the shortcut of simply searching for those iconic textures and sounds on the internet (which was not allowed as per brief), the student acquired all textures and audio by taking screenshots and recordings in-game, the equivalent of taking photos and audio recordings of real world locations.
- A recreation of a local football field with functional ball mechanics and wind simulation.
- A fully "playable" recreation of a group's favourite skate park, using field recordings of surfaces, the sky and surroundings, and actual audio recordings of their boards. The experience included a physical skateboard simulation that allows for moving around and performing a small set of stunts.
- An architectural pre-visualisation of a house using only the in-built primitive shapes of Unity, such as cubes, spheres, cylinders, capsules, and applying a large range of transformations.
- A lot of student flats and bedrooms during the 2020/2021 COVID-19 lockdown periods.
- A recreation of the Auckland Art Gallery with a large range of paintings that were exhibited at that point in time.
- The interior of an Air New Zealand Boeing 787.
- Fully functional horror scenarios, e.g., haunted houses or a haunted university campus, including scripted shock effects and spatialised audio.

5.2 COMP770 - Virtual and Immersive Environments

Assessment in COMP770 consists of three parts. At first, student groups pitch their project idea using some literature research or contextual scoping, sketches, and justification for the use of XR technology. This part forms 20% of their final grade. In this pitch, students could justify gaining access to a more complex XR hardware, e.g., due to the need for 6DoF tracking to implement redirected walking.

The students are also provided with a selection of project briefs, e.g., prototypes for collaboration partners from industry, or for other research units from AUT. One example is a brief for creating a customiseable environment for a research project around the influence of the environment on the taste of food [Xu et al. 2019], also listed below in the examples.

In the second assessment part, worth 60%, the groups implement the project, incorporating the feedback given for the first part. The process needs to be documented, and this documentation is submitted in addition to the final Unity project. To allow for individual marking adjustment, a table with the group members' contribution and signatures is required.

Immediately after the deadline of the second part of the assignment a showcase day is run where the groups not only show their projects to each other, but also have a chance to collect data for their final part of the assignment.

That last part, worth 20%, is an individual reflection on the project development as well as the showcase "test", including an evaluation of the data collected from the showcase.

The showcase has always been a day of excitement and high energy (see Figure 1, right). Usually, students invite friends, and in the week leading up to it, a call goes out to the rest of the BCT students to attend as well. Sadly, in 2020 and 2021, this format had to be abandoned and then significantly modified due to COVID-19. In 2020, it was replaced by a video submission and the test "population" being mostly the immediate household members. In 2021, in-person classes had mostly resumed, but stringent hygiene protocols were in place. Therefore, we gave students the option for either a video submission, or to turn up to showcase day, providing a larger space for maintaining social distancing, means to clean headsets and other equipment, and disposable VR-suitable face masks.

The following examples showcase the large variety of submissions:

- *STEM Rocket* (see Figure 2): This educational VR app teaches the basics of how a rocket works, with a puzzle that needs to be solved to successfully create combustion (add air, fuel, heat), a puzzle to solve to open the hangar doors, a control panel to experiment with thrust to achieve lift-off, and a final scene "riding" on the rocket into space.
- *Taste Research Environment*: This project was created in response to a brief created by a research unit at AUT who looks at differences in taste when experiencing different environments [Xu et al. 2019]. It allows to change a bar environment, e.g., the look and colours, patronage density, noise, and music.
- *Fire Safety Experience*: An educational VR experience that requires the user to find all possible fire hazards in a house before going to bed. While some of those hazards are easy to spot, e.g., a candle left burning on the table, others are trickier, e.g., the expired battery in the smoke alarm.
- *Orbital Cleanup Crew*: A fictitious VR experience in which the user needs to clean up space junk by marking it with a laser and then activating the spaceship's grapple magnet. Over the course of the game, ranging from 1980 to the present, the density of the junk intensifies to the point of absolute futility.
- *Matariki AR*: An educational AR experience about the star constellation of Pleiades, and it's pivotal role for the Māori New Year. The application lists the names of the stars, their role in the Matariki lore, and their connection to the natural environment. The application also includes minigames such as picking up and sorting rubbish correctly as a "kaitiakitanga" activity (guardianship over/protection of the natural environment).
- *VR CoOp Puzzle Game*: In this cooperative game, one player uses the headset and finds themselves in a dungeon with hieroglyphs and needs to describe the room and arrangement of the symbols to the other player(s) who use printed information to solve the puzzles.
- *Dementia Simulator*: In this experience, the user walks through a garden and into a house, which gradually loses colours and geometry, representing the loss of memory and cognitive ability through dementia.

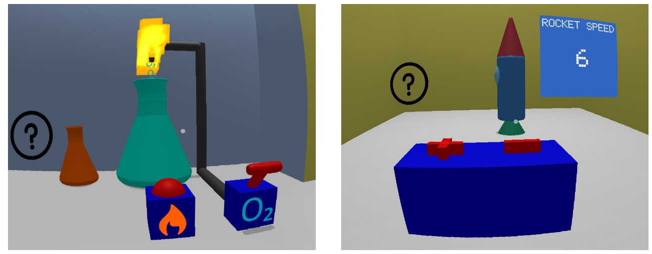

Figure 2: Example of an Assignment 2 submission for COMP770 – "STEM Rocket", a Google Cardboard VR puzzle game for teaching basic principles of rocket science.

- *EyeSpy*: In this exploration game, the user has to find certain elements by spatial audio clues only.

6 EVALUATION

AUT has always had a practice of evaluating courses towards the end of a semester. While those were initially paper-based, 2015 saw the introduction of the electronic Student Paper Experience Questionnaire (SPEQ). This system allows lecturers to arrange a set of questions that can be selected from a catalogue. The minimum amount is five questions, the maximum allowed is seven. Most of those questions use a 5-point Likert-Scale with a score of 1 (strongly disagree) to 5 (strongly agree). Some questions are open-ended and allow a text reply.

There are two kinds of SPEQs: one for the course as such (content, delivery, assessment, workload), and one for each staff member who delivered the course. In this paper, we concentrate on the course-related results, but also briefly discuss the personal results in Section 7.

SPEQs are opened up to students through the last four weeks of the semester. After that, staff members receive an anonymised and summarised report of the results. The report compares the averaged scores of the same questions in a) courses of the same level, b) courses in the same subject area, c) courses in the school, d) the faculty, and e) the university. For this paper, we compare the course scores with those of the faculty, as that encompasses all schools and degrees that have some relation to the content taught in CTEC601 and COMP770, but avoid comparisons with completely different disciplines such as health or hospitality.

For both courses, the questions chosen from the catalogue were the same:

Q1: I was generally given enough time to understand the things I had to learn.
Q2: The teaching stimulated my interest in learning more about the subject.
Q3: The learning resources in this paper supported my studies.
Q4: The assessments in this paper were a fair measure of my learning.
Q5: The staff made it clear right from the start what they expected from students.
Q6: The paper was well organised and ran smoothly.
Q7: Overall, I was satisfied with the quality of this paper.

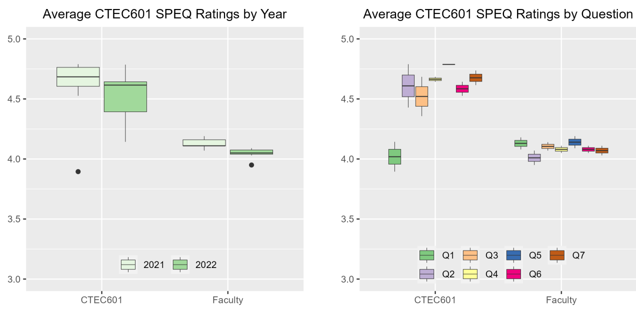

Figure 3: CTEC601 SPEQ results by year (left) and by question (right). Note that the Y axis starts at 3.

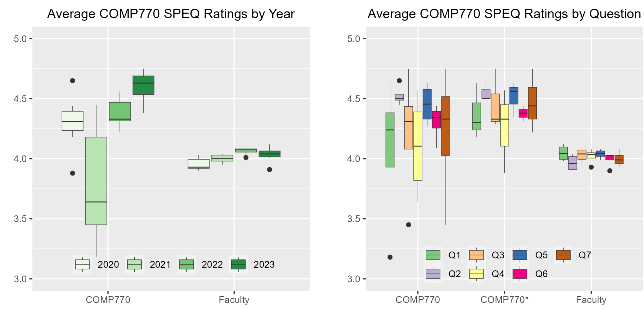

Figure 4: COMP770 SPEQ results by year (left) and by question (right). Note that the Y axis starts at 3.

In the following subsections, we are going to compare the ratings of those questions aggregated by year or by question, compared to the results from the faculty using an unpaired t-test. While the Faculty results are normally distributed, some of the results from the courses might not be. Also, the response rate to the SPEQs varies over the years, and does not represent all students enrolled in the course.

6.1 CTEC601 - Synthetic Realities

For this course, we only have two years of data as a) it had not been taught from 2018 to 2021 (see Section 2.3) and b) at the time of writing, delivery of the course had just begun.

In general, the ratings of the course (see Figure 3) averaged over all questions are above the Faculty ratings for both years (2021: Course=4.59, Faculty=4.13, $p<0.003$; 2022: Course=4.52, Faculty=4.06, $p<0.001$).

An analysis of the ratings for the individual questions does not make much sense as there are only two data points, and most p-values are above 0.05, but again, except for Q1, all questions have been rated higher than Faculty. The ratings for Q1 (“I was generally given enough time to understand the things I had to learn”), especially low in 2021, are a reflection of the dense course material. This is also evident in the qualitative feedback, where the aspects “a lot to take in” and “at times a bit rushed” appear relatively often. However, in the same sentences, students usually also mention the advantage of being able to use the recorded lectures to re-watch those elements (see Section4). Still, we adjusted the content by removing some less important parts, and the higher ratings for Q1 in 2022 proved this to be a good decision.

Also, the total absence of negative feedback about the dreaded “programming” seems to indicate that the provision of ready-made code modules works well for the students. Despite each of them being rather simple and specific, in several of the submitted assessments, the arrangement of those modules was quite sophisticated, e.g., to construct logical puzzles with combination locks, the control mechanism of an automatic bowling alley (see Section 5.1).

6.2 COMP770 - Virtual and Immersive Environments

Although we have SPEQ data from 2015 onward, we are only presenting the time period starting in 2020 as that was the year where the structure of the assessments as well as the delivery mode changed (see Section 4.2).

Similar to CTEC601, the ratings of the course (see Figure 4) averaged over all questions are above the Faculty ratings, except for 2021 (2020: Course=4.30, Faculty=3.96, $p<0.003$; 2021: Course=3.79, Faculty=4.00, $p=0.268$; 2022: Course=4.38, Faculty=4.06, $p<0.001$; 2023: Course=4.60, Faculty=4.03, $p<0.001$). The low results in 2021 together with qualitative feedback clearly indicated the need for offloading the basics of computer graphics and authoring 3D environments via Unity Engine into CTEC601 instead of having it packed into COMP770 as well. A lot of the qualitative SPEQ feedback mentioned the “deep end” of having to deal with learning how to use the Unity Engine on top of also getting to grips with the concepts of XR. After the re-introduction of CTEC601 in the second half of 2021, the results clearly improved in 2022 and 2023, when CTEC601 students would continue into COMP770.

The 2021 results also distort the graph for the responses broken down into the questions. In Figure 4 (right), the middle column “COMP770*” shows the results without the 2021 data. In general, all questions are rated significantly higher than the Faculty average, except for Q1 (“I was generally given enough time to understand the things I had to learn”) and Q4 (“The assessments in this paper were a fair measure of my learning.”), again highlighting the issues around the very compact course content and the hurdle of having to learn how to use the Unity Engine on top.

7 DISCUSSION

The evaluation of the two respectively four years of data from the two courses paints the picture of a bumpy journey with a positive outcome. Being able to separate 3D content creation with a game engine from XR development by running two courses instead of just one was a reasonable decision, suited the new intake of architecture students better, and the transition from one course to the next became easier.

The multidisciplinary nature of the enrolments in conjunction with the group-based assessments has the advantage of closely mirroring the setting in the workforce. In the majority of the cases, the groups work well. There is an obvious tendency of the students from their respective degrees to “stick together”, but some groups also take the opportunity to open up to different perspectives and ways to approach problems. Overall, in the six occurrences of the courses, we had only two group "implosions" that could not be solved and required a very careful approach to marking.

In general, we inform the students in advance that group formation and conflict resolution is normally not the task of the teaching staff. What we can do is provide tips and technical skills for sharing work and 3D projects (e.g., cloud-based storage, GitHub [GitHub Inc. 2023], divide-and-conquer). However, since the soft skill of collaboration is not explicitly taught in any course, giving some advice during challenging situations is a welcome "in-situ" learning opportunity.

With respect to the software modules we provide, it could be argued that for COMP770, the Unity XR Interaction Toolkit can be used instead [Unity Technologies 2023d]. However, when comparing the complexity of such framework with our relatively simple but versatile modular framework, and the often surprisingly complex outcomes students have created using it, we are hesitant to initiate this transition (see Section 6).

Last, but not least, something that is not discussed in detail in this paper, but has been evident in every lecturer-related SPEQ feedback form (see Section 6), is that of passion. Despite having problems with the content being "dense" and assessments and circumstances during COVID-19 challenging, the students react very positively to passionate teaching staff. Sample comments in the qualitative feedback are: "[lecturer name] is always enthusiastic about seeing peoples projects come to life. This passionate environment is very fun to learn in and really helps to stay motivated with the work." or "[lecturer name] …could make me enthusiastic about learning how to watch paint dry." Being upfront with expectations, clear in communication, and honest when making mistakes is also valued highly by the students.

8 CONCLUSION

In this paper, we have presented the context, course design, assessment strategies, and evaluation based on student feedback of two courses about computer graphics and XR. Especially with respect to equipment, obsolescence, and resourcing, challenges had to be overcome, and the mode of delivery had to be adapted during the COVID-19 pandemic. We hope some of the solutions, ideas, and recommendations are helpful for the reader despite the circumstances likely being very different in other institutes and schools.

ACKNOWLEDGMENTS

Thanks to Sameera Menezes for managing the student cohorts during the teaching periods and providing us with the enrolment data.

REFERENCES

Adobe. 2023. *Adobe Creative Cloud for students and teachers | Adobe Creative Cloud.* Adobe. Retrieved 2023-08-02 from https://www.adobe.com/nz/creativecloud/buy/students.html

Gökçe Akçayır and Murat Akçayır. 2018. The flipped classroom: A review of its advantages and challenges. *Computers & Education* 126 (2018), 334–345. https://doi.org/10.1016/j.compedu.2018.07.021

Ron Amadeo. 2021. *Google's VR dreams are dead: Google Cardboard is no longer for sale.* Ars Technica. Retrieved 2023-08-02 from https://arstechnica.com/gadgets/2021/03/googles-vr-dreams-are-dead-google-cardboard-is-no-longer-for-sale/

Apple Inc. 2023. *ARKit 6 - Augmented Reality.* Apple Inc. Retrieved 2023-07-28 from https://developer.apple.com/augmented-reality/arkit

Blender Foundation. 2023. *blender.org - Home of the Blender project - Free and Open 3D Creation Software.* Blender Foundation. Retrieved 2023-08-02 from https://www.blender.org/

Rory Brown. 2023. VRcompare - The Internet's Largest VR & AR Headset Database. Retrieved 2023-08-02 from https://vr-compare.com/

GitHub Inc. 2023. *GitHub.* Retrieved 2023-08-02 from https://github.com

Google Inc. 2023a. *Build new augmented reality experiences that seamlessly blend the digital and physical worlds | ARCore | Google for Developers.* Google Inc. Retrieved 2023-07-26 from https://developers.google.com/ar

Google Inc. 2023b. *Cardboard Viewer Profile Generator.* Google Inc. Retrieved 2023-08-02 from https://wwgc.firebaseapp.com/

Google Inc. 2023c. *Open Source Cardboard SDK.* Google Inc. Retrieved 2023-08-02 from https://developers.google.com/cardboard

HP Development Company. 2023. *HP Windows Mixed Reality Headset - Professional Edition Specifications | HP® Customer Support.* HP Development Company. Retrieved 2023-08-02 from https://support.hp.com/au-en/document/c06112636

HTC Corporation. 2023. *VIVE Pro.* HTC Corporation. Retrieved 2023-08-02 from https://www.vive.com/nz/product/vive-pro-full-kit/

Hypergrid Business. 2023. *VR Headset QR Codes — Hypergrid Business.* Hypergrid Business. Retrieved 2023-08-02 from https://www.hypergridbusiness.com/faq/vr-headset-qr-codes/

Juan Linietsky and Ariel Manzur. 2023. *Godot Engine - Free and open source 2D and 3D game engine.* Retrieved 2023-08-02 from https://godotengine.org/

Stefan Marks. 2023. *Sentience Lab Unity Framework.* Auckland University of Technology. Retrieved 2023-08-02 from https://github.com/stefanmarks/SentienceLab_UnityFramework/tree/v1.7

Meta. 2023. *Meta Quest 2.* Meta. Retrieved 2023-08-02 from https://www.meta.com/nz/quest/products/quest-2/

Microsoft. 2021. *HoloLens (1st gen) Hardware.* Microsoft. Retrieved 2023-08-02 from https://learn.microsoft.com/en-us/hololens/hololens1-hardware

Muse Group and contributors. 2023. *Audacity ® | Free, open source, cross-platform audio software for multi-track recording and editing.* Muse Group and contributors. Retrieved 2023-08-02 from https://www.audacityteam.org

OBS Studio Contributors. 2023. *Open Broadcaster Software | OBS.* OBS Studio Contributors. Retrieved 2023-08-02 from https://obsproject.com/

Fezile Ozdamli and Gulsum Asiksoy. 2016. Flipped Classroom Approach. *World Journal on Educational Technology: Current Issues* 8, 2 (2016), 98–105. https://eric.ed.gov/?id=EJ1141886 Publisher: SciencePark Research, Organization & Counsesling ERIC Number: EJ1141886.

Jay Peters. 2019. *Google is open sourcing Cardboard now that the Daydream is dead.* The Verge. Retrieved 2023-08-02 from https://www.theverge.com/2019/11/6/20952495/google-cardboard-open-source-phone-based-vr-daydream

Mark Sawicki and Juniko Moody. 2020. A Brief History of Computer Graphics. In *Filming the Fantastic with Virtual Technology.* Routledge, 2 Park Square, Milton Park, Abingdon, Oxon OX14 4RN, 21–58.

Sysdia Solutions Ltd. 2023. *VRTK v4 Tilia Package Importer | Utilities Tools | Unity Asset Store.* Sysdia Solutions Ltd. Retrieved 2023-08-02 from https://assetstore.unity.com/packages/tools/utilities/vrtk-v4-tilia-package-importer-214936

The GIMP Team. 2023. *GIMP — GNU Image Manipulation Program.* The GIMP Team. Retrieved 2023-08-02 from https://www.gimp.org/

The Khronos Group Inc. 2023. *OpenXR Overview - The Khronos Group Inc.* The Khronos Group Inc. Retrieved 2023-08-02 from https://www.khronos.org/openxr

Marcus Toftedahl and Henrik Engström. 2019. A Taxonomy of Game Engines and the Tools that Drive the Industry. In *Proceedings of the 2019 DiGRA International Conference: Game, Play and the Emerging Ludo-Mix.* DiGRA, Kyoto, Japan, 17. http://www.digra.org/wp-content/uploads/digital-library/DiGRA_2019_paper_164.pdf

Unity Technologies. 2023a. *OpenXR Plugin | OpenXR Plugin | 1.7.0.* Unity Technologies. Retrieved 2023-08-02 from https://docs.unity3d.com/Packages/com.unity.xr.openxr@1.7/manual/index.html

Unity Technologies. 2023b. *Unity Real-Time Development Platform.* Unity Technologies. Retrieved 2023-08-02 from https://unity.com

Unity Technologies. 2023c. *Unity's AR Foundation Framework | Cross platform augmented reality development software | Unity.* Unity Technologies. Retrieved 2023-08-02 from https://unity.com/unity/features/arfoundation

Unity Technologies. 2023d. *XR Interaction Toolkit | XR Interaction Toolkit | 2.4.3.* Unity Technologies. Retrieved 2023-08-02 from https://docs.unity3d.com/Packages/com.unity.xr.interaction.toolkit@2.4/manual/index.html

Valve Corporation. 2015. *SteamVR - OpenVR SDK Now Available - Steam News.* Valve Corporation. Retrieved 2023-07-28 from https://store.steampowered.com/news/app/250820/view/2898585530113913716

Niek van der Maas. 2023. *OBS-web - the easiest way to control OBS remotely.* Retrieved 2023-10-09 from https://github.com/Niek/obs-web

Yun Xu, Nazimah Hamid, Daniel Shepherd, Kevin Kantono, and Charles Spence. 2019. Changes in flavour, emotion, and electrophysiological measurements when consuming chocolate ice cream in different eating environments. *Food Quality and Preference* 77 (Oct 2019), 191–205. https://doi.org/10.1016/j.foodqual.2019.05.002