Development of an XR-Art Studio Application to Enhance Remote Learning of the Traditional Arts

XRAS

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The Importance of XR-Art Studio Application for the delivery of Studio Arts Instruction

Our team, composed of computer science and fine art students under the supervision of professors at Ontario Tech and OCAD U, created an eXtended Reality (XR) Art Studio (XRAS) application (App) to enhance remote-learning for the traditional Fine Arts. The XRAS App provides instructors and learners with a tool that addresses learning gaps associated with fundamental colour theory and colour mixing.

The shift from in-person studio instruction to virtual classrooms, accelerated by the COVID-19 pandemic, revealed many learning disparities in the visual Arts associated with developing proper prediction of colour to nurturing colour sensitivities of cross-cultural perspectives. Our XR learning tool assists students both in the context of their own work and a broader artistic discourse, enabling a new generation of creators to develop transferable knowledge as well as psychomotor skills. Combining the Game and XR development expertise at Ontario Tech University with the Traditional Fine Arts expertise at OCADU, the XRAS is an innovative and effective solution to the challenges presented by remote learning.

The XRAS app simulates the fundamental aspects of a traditional art studio using XR to bring the studio into students' own homes. XR, an umbrella of rapidly-advancing, immersive technologies including virtual (VR), augmented (AR) and mixed (MR) reality. XR is an exciting tool for developing engaging virtual experiences for creators, facilitating the visualization and practice of skills otherwise dependent on specialized equipment and in-person educational settings. XR provides opportunities to democratize and disseminate learning tools cost-effectively and enables long-distance collaboration from urban to remote communities, both at home and abroad.

Our pedagogical framework for the XRAS app centered around two distinct pillars- to explore freeform like one would in a sketchbook, and another to learn through tutorial modules. In the modules, students progress through a series of foundational colour theories to guide them through the basics of colour matching, complementary colours, hues/values, in an interactive manner. Each learning module consists of a theoretical component where students are presented with a focused lesson followed by an interactive exercise to gauge progress/knowledge. Essentially, XRAS app acts as a helpful mobile colour theorist for remote learning.

Colour Theory

Brief Introduction

Color Theory acts as a guide for artists and designers to help mix and use colour consistently and accurately for desired combinations. It has a variety of applications - most essentially, colour theory can bring logic and structure to the perception and variability of colour.

Colour theory is used by fine artists - like painters & sculptors - as well as designers, illustrators, filmmakers, and stylists. Any profession that depends on the use of colour can benefit from colour theory. The way colour theory is exemplified varies - a wheel, a grid, a line, in 3D, in 2D, via subtractive or additive methods - although similar goals are investigated by all.

Colour theory has a plethora of uses. For example, it can help create harmony or tension, navigate the eye, accentuate subject matter, tell a story, set the mood or express emotion. It is invaluable for artists and students of colour.

XRAS Framework

The XRAS research team used the Johannes Itten colour wheel (fig.1). Each of the learning exercises in the XRAS application use the Itten colour wheel because of its pedagogical clarity, as it offers a visual guide to distinguish between the primary, secondary and tertiary colours. This twelve-part colour circle makes colour selections easy for novice learners, emphasizing colour via strategic graphical geometric shapes. We used the same geometric shapes in the wheel to visualize the completion of lessons, for other gamification strategies in the app and more broadly as a navigation tool in the user interface.

Itten's colour wheel and teachings serve as the framework for the Bauhaus artistic movement, notably inspiring the seminal colour theorist and artist Joseph Albers, a student of Itten's. *The Art of Color* (Ittens, 1961) and *The Interaction of Colour* (Albers, 1963) were used in the research and development of the XR-Art Studio app.

Fig.1 Johannes Itten Colour Wheel. Published in The Art of Color, 1961
Based on the study of colour by the Bauhaus.

The following visual examples represent the 8 basic colours theories explored in the learning modules in the XRAS app: values, monochromatic hues, high key and low key palettes, complementary & split complementary colour theory, saturation / de-saturation and colour weight.

Value Scale

Monochromatic

High Key

Low Key

Complimentary

Split Complementary

Saturation

Colour Weight
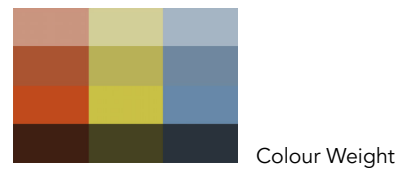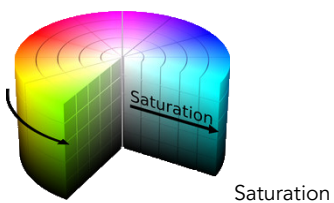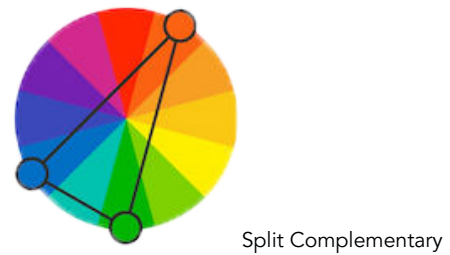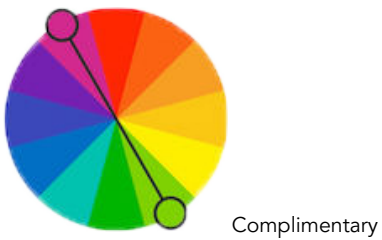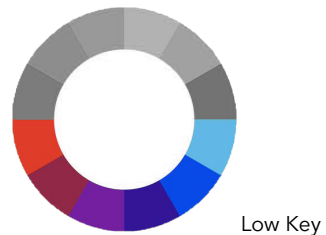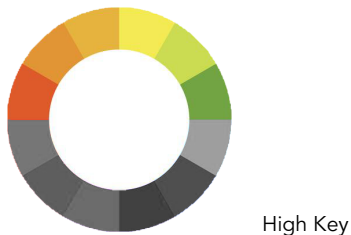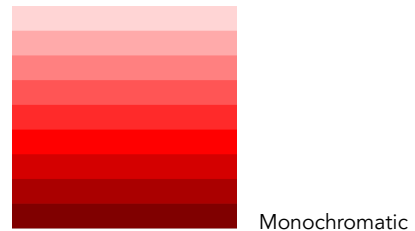
The XR Art Studio app modules were modeled by Professor Szkudlarek's (a painter and XRAS project collaborator) syllabus at the Ontario College of Art and Design University in her Painting 1 & Painting 2 Undergraduate classes, compulsory to all incoming Drawing & Painting students. The introductory courses teach the same 8 colour theories as those in the XR Art Studio application, and are common in Design and Art departments across the country.

Colour Relativity

Joseph Albers notably identified that all colours are relative - their appearance changes according to what colours they are near. For example, a light green may appear darker next to a pale yellow, shifting a desired high key colour combination into a mid-key colour combination. That relativity is difficult for beginning students to comprehend, because not all yellow is *x* and not all green is *y*.

This is an important distinction that makes our XRAS app an innovative response to challenges of teaching colour theory remotely. XR technology is sensitive enough to detect the saturation levels of a colour, providing a more accurate assessment of the optimal colour applications. The XRAS app provides a road map for students to practice and explore their understanding of hues, tones, shades, saturations and colour relativity.
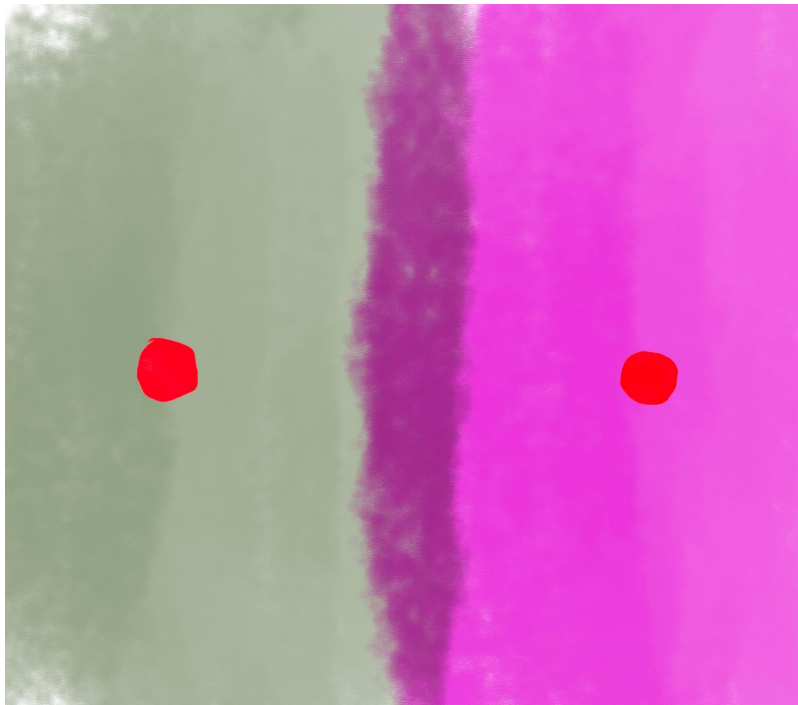
To provide further context, the examples below are a series of exercises proving the relativity of colour. The smaller colours in the middle of the squares are the same colour, however the context of the other colours around it cause the eye to interpret them differently.

Joseph Albers, The Interaction of Colour, 1963
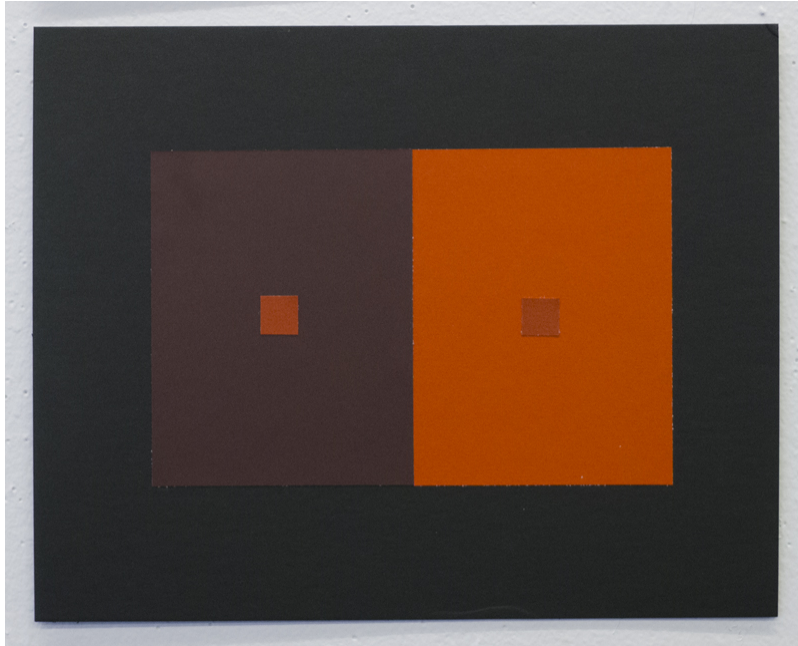
Joseph Albers, The Interaction of Colour, 1963

Veronika Szkudlarek, Digital colour experiment following Albers colour theory exercises in *The Interaction of Colour, 2022*

Practice & Theory

The framework for XRAS app was developed as an assistant to students learning - students practice and explore *while* using the theories in the application. This system engages the mobile app as a type of instructor in a classroom, helping to check the accuracy of the theory being explored. That hybridity between physical practice of making while engaging in theory has proven benefits for student learning. Albers writes in *Interaction of Color* about the importance of this type of model.

Albers writes:

> *"[Interaction of Color] reverses this order and places practice before theory, which after all, is the conclusion of practice. … Just as the knowledge of acoustics does not make one musical — neither on the productive nor on the appreciative side — so no color system by itself can develop one's sensitivity for color. This is parallel to the recognition that no theory of composition by itself leads to the production of music, or of art.*
>
> *Practical exercises demonstrate through color deception (illusion) the relativity and instability of color. And experience teaches that in visual perception there is a discrepancy between physical fact and psychic effect. What counts here — first and last — is not so-called knowledge of so-called facts, but vision — seeing. Seeing here implies Schauen (as in Weltanschauung) and is coupled with fantasy, with imagination."*

Albers is describing the importance of pairing theory with the act of seeing - of experiencing the perception of colours. XRAS, although in a prototype phase with space for improvement, is innovative because it pairs practice with theory. Students make paintings and colour relationships, and then access the XR capability in the app to determine the success of the experiment. Examples of student use provided below.

With the advancement of technology we can significantly expand options for how to teach theory to traditional artists. This application was made as a response to a widening learning gap that was observed at the Ontario College of Art and Design University during online and hybrid instruction, and acts as both a teaching tool for students as well as a way to gauge success of the applied theory.

Design of the App Prototype

Disclaimer: the XRAS app is a prototype and is the result of extensive experimentation with new ideas for use in a traditional art setting. Thus it is not bug-free and has room for aesthetic improvement and design. We see this as a first step and proof-of-concept and provide the entire codebase here for the community to suggest and make improvements. As such, we encourage additional development and ideas from the community.

The XRAS was designed with the intention of having students be able to Explore techniques and tools on their own and learn about fundamental colour theory using guided tutorials. Fundamentally, we believe that some students want to pick up the app and try out the XR based tools while others learn better through guided practice. Each course that utilizes these approaches can point students towards the tutorials for guided practice but they can complete the learning outcomes simply through use of the exploration mode.

Explore Mode

Our goals for the explore mode was to allow students to engage in using XR tools during their artistic practice. We wanted to 'augment' their practice rather than dictate their practice. To do so, we identified the core tools necessary for aiding a traditional painting practice to be:

Image Augmentation

- Ability to take pictures of your own painting and draw/annotate on top in order to test out various ideas. Users can take a picture of their painting and make annotations using the color picker tools as seen in this image below. This works best on an iPad using an Apple Pencil due to the larger screen size and control of the pencil for annotation. The student can make notes or test out different color combinations prior to committing to a particular physical paint mix.
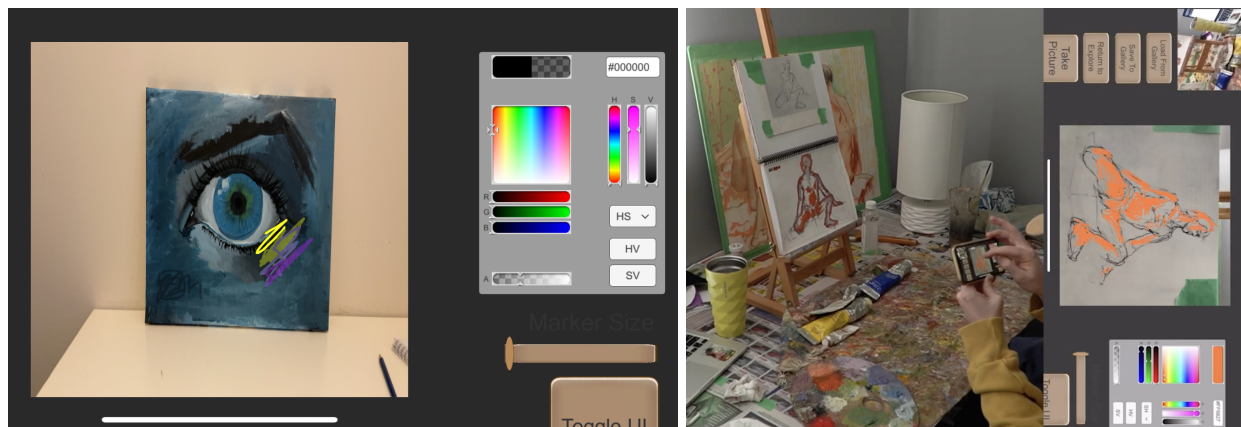
Perspective Lines Overlay

- ○ A common issue students face is using incorrect perspective in their drawings and paintings. We provide a tool that allows students to place 'perspective points' on their real painting allowing the app to draw perspective lines emanating from this point. This allows students to re-evaluate the perspective of their drawings and paintings periodically to inform their process.
- ○ Example of Placing an AR Single Vanishing Point and examining the painting:
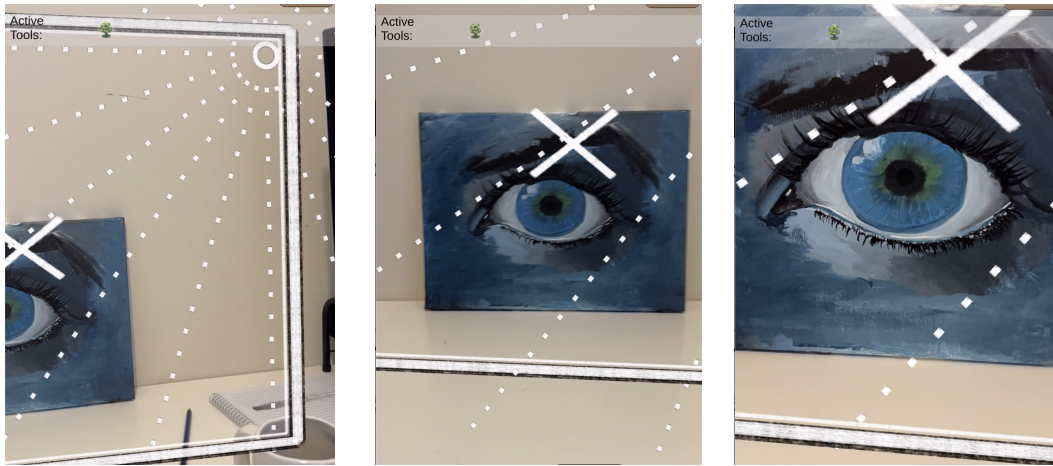
- ● Example of placing a second Vanishing Point on the left side and examining the painting closely
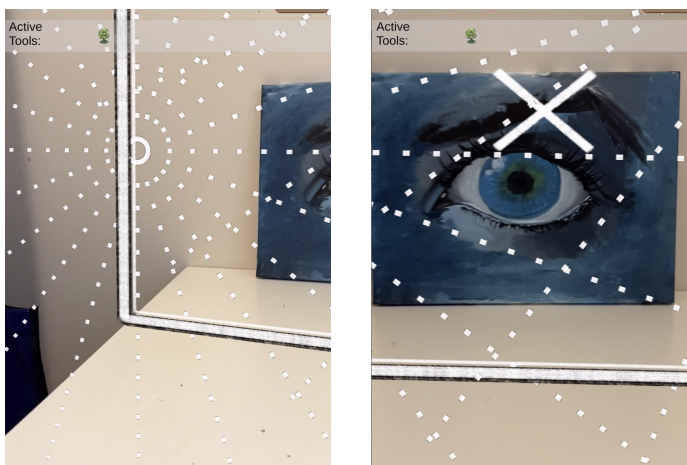
- ● Video Demonstration can be found here:
  https://www.youtube.com/watch?v=Uw_lGM-gZRs

Image Reference Overlay

- ○ Search for images or add images from your phone as reference the scene and place them beside your own painting in AR
- ○ We utilize the AR capabilities of your phone to find and select a plane you wish to place an object relative to your physical painting. This allows the painter to see in-context differences between value, hue, and proportions that can inform their practice.
- ○ Placing a reference image in AR on different planes near the physical painting

- ○ Video Demonstration can be found here:
  - ■ https://www.youtube.com/watch?v=idjfk4csP5M
 - ■ https://www.youtube.com/watch?v=PXVY61x4ygU
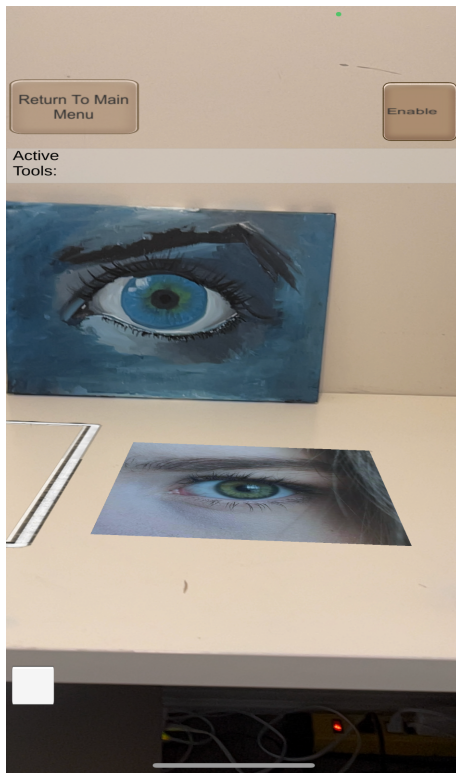
Palette Creator/Colour Picker

- Ability to select colours from a live view from the phones camera and create a palette that can be saved to an internal database and used later
- We envision this as being the starting point for being able to create reference palettes from real-world scenes and a great tool for artists to use when they see an object or environment in the real world they think would be great to incorporate into their work. Traditional painters tend to develop physical paint swatches and document how that colour-mix is created with paint, we wanted to augment this experience by enabling them to document interesting colour choices and combinations they see in the real world that they can investigate later with traditional paints.
- The user can select a number of samples from the scene to store on the side and/or click on the Generate Palette button which uses Computer Vision techniques to perform an automatic identification and extraction of the 5 most common distinct colours found in the scene. This auto-generation is useful for gaining a better understanding of the colour structure of the scene.
- The user can also select "show colors" which overlays a series of colours corresponding to various corresponding colour theories (complementary, triadic, etc) from the currently selected colour (the last one the user selected).
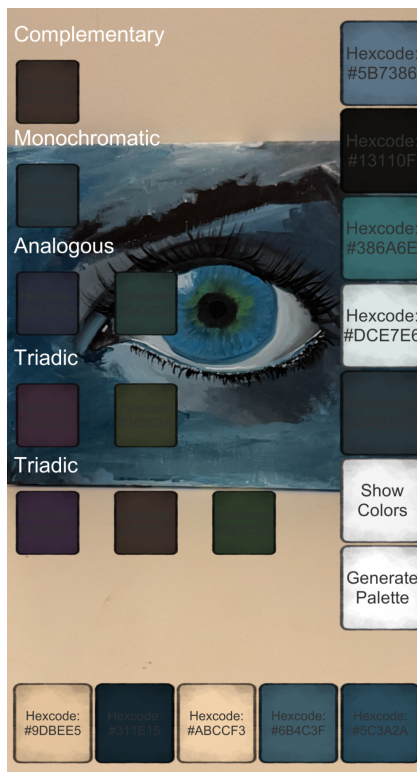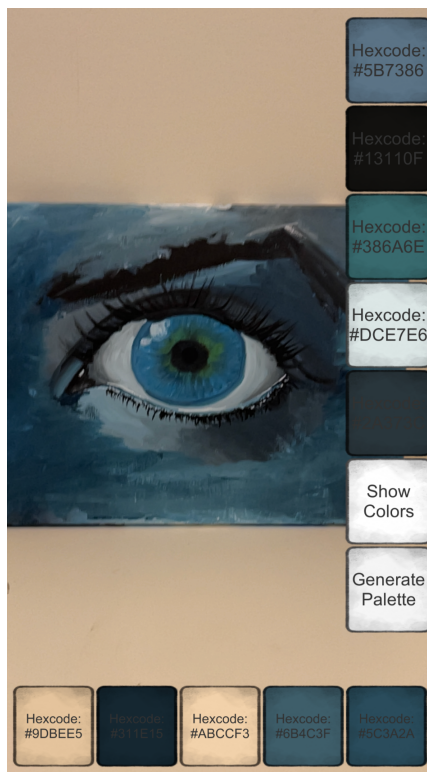
Digital Calipers

- Ability to use digital calipers to measure distances on their paintings with respect to their reference.
- The intent of this tool was to be able to overlay and interact with a set of digital calipers that can be moved in AR to various parts of the scene to allow the student to have an indication of proportions and distances. For example, it would be possible to use the calipers to see if the eyes are the same distance apart as a reference model in a portrait situation.
- Here is an example of overlaying the calipers to measure the distance between these buildings to provide an indication of proportionality.
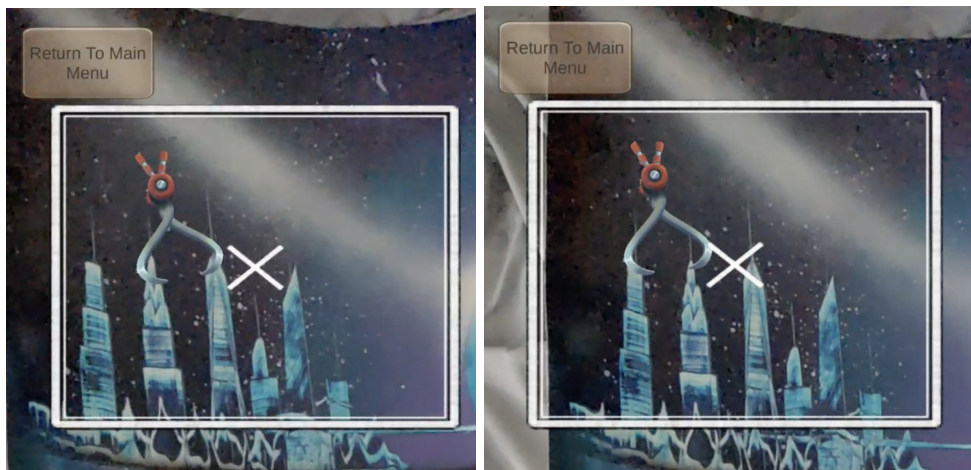
- Another example of using measuring with the calipers:
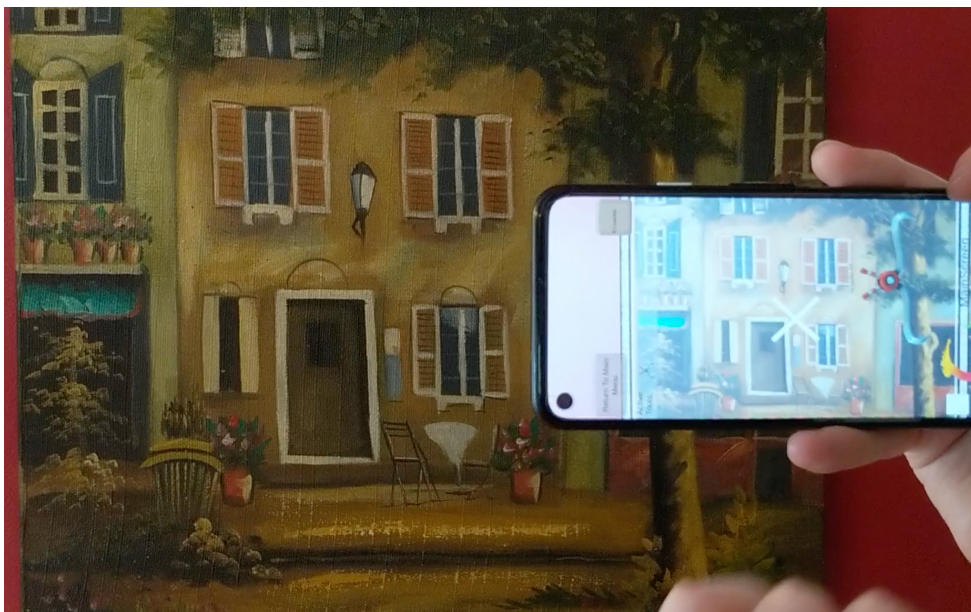
Tutorial Mode

Our goals for this mode was to develop a series of goal-oriented tutorials that students could use in their own practice and use the tools to explore options for their paintings and while doing so learn the importance of Value and colour theory. We had designed a number of tutorials and metrics to use that were in development. Unfortunately the implementation was lost due to hardware failure on one of the student computers and we were unable to recover the files.

The following are a selection of examples from the tutorials found in XRAS app.
Lesson objectives and lesson details are detailed, as well as a storyboard for how students used the app while painting. Final examples of completed paintings are also included.
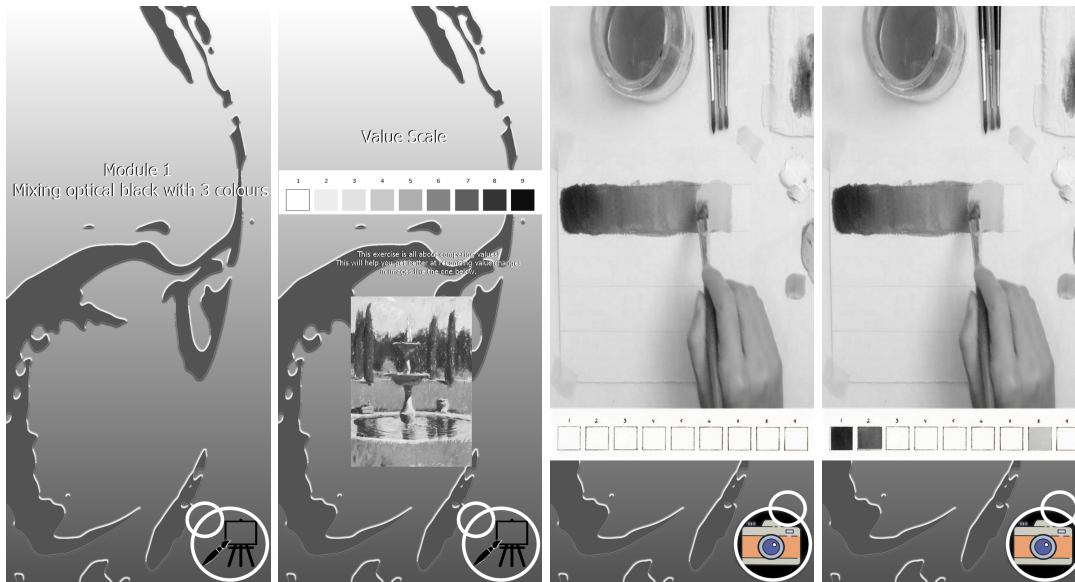Value Scale

Lesson Objective:

To allow students to explore value and get feedback on their paint mixing while creating a value scale.

Lesson Details:

The students will be shown a value scale and example of a value scale being developed. They are then asked to create one on paper and the app will analyze the produced image using computer vision techniques to identify which values are present and which are missing. The students will then be shown which are missing and be prompted to re-create the scale until they achieve the complete set of values.
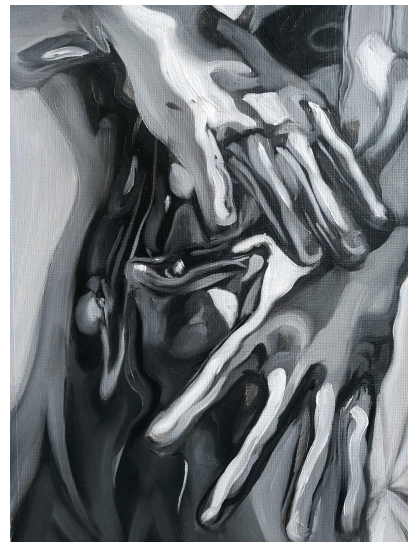
Storyboard:

Final Painting Example Using XRAS Tutorial Guide:
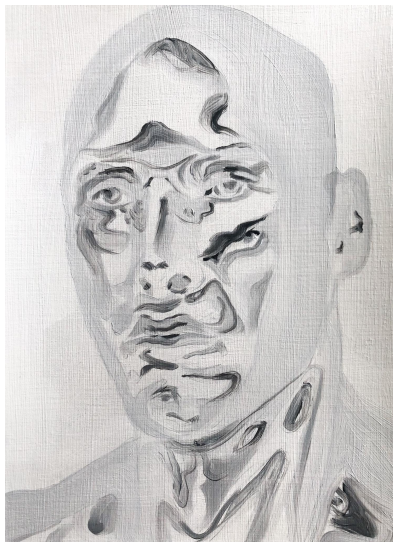
Ethan Platt, Value Scale, oil on canvas, 2022

Ethan Platt, Value Scale, oil on canvas, 2022
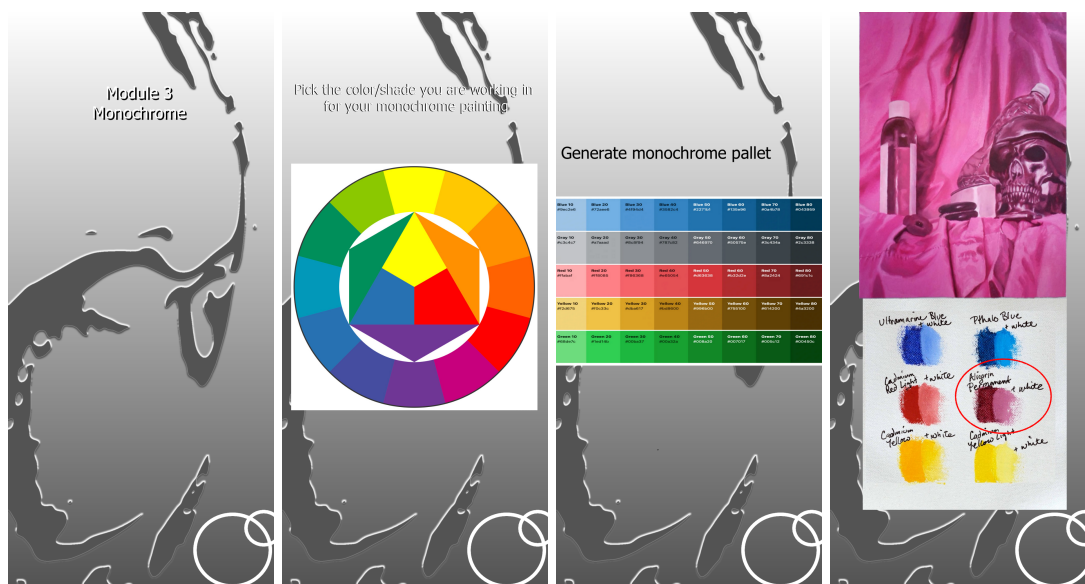
Monochrome Palette

Lesson Objective

The goal for this lesson is to aid the student in the creation of a monochrome palette and painting with this palette.

Lesson Details:

Students will be asked to select a colour they wish to use for their painting. From there a monochrome palette will be shown to them using the selected colour followed by a prompt to have them create their own monochromatic palette with this colour. They can then use this as a guide during their palette creation and develop a painting with this palette. They can then use the palette generator tool to analyze their resulting painting and see how their final result compares to their chosen palette.

Storyboard:

Final Painting Example Using XRAS Tutorial Guide:

Ethan Platt, Underpainting, oil on canvas, 2022

Ethan Platt, FInal Monochromatic, oil on canvas, 2022

High Key

Lesson Objective:

The goal for this lesson is to aid the student in the creation of a High Key palette and make a painting with this colour theory.

Lesson Details:

Students will be asked to select the module entitled High Key. From there a high key palette will be shown to them using the selected colour followed by a prompt to have them create their own high key palette. They can then use this as a guide during their palette creation and develop a painting with these colours. They can then use the palette generator tool to analyze their resulting painting and see how their final result compares to their chosen palette.

Storyboard:

First the student uses the App on the reference to select an appropriate palette using the palette generator.

Next, the student begins painting and uses the app to re-evaluate periodically using the palette tools to verify.
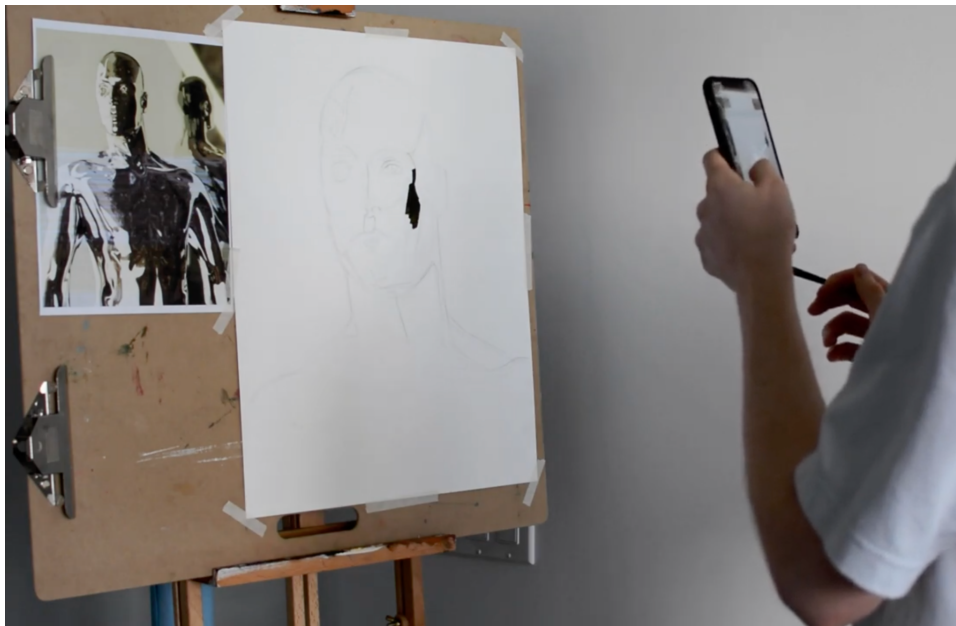
The student continues to paint and use the app to reevaluate their palette and uses the perspective lines tool to verify their perspective.
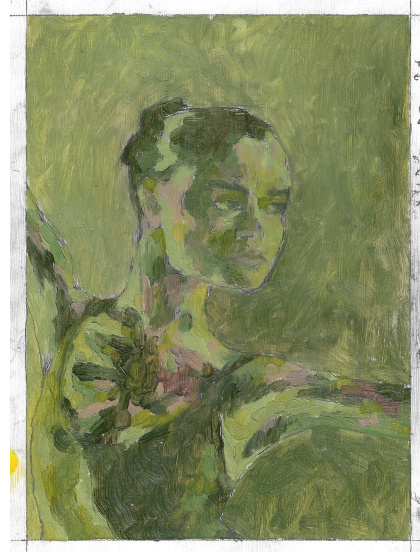

Final Painting Example Using XRAS Tutorial Guide:

Ethan Platt, High Key, oil on canvas, 2022

Connor Rothe, High Key, oil on canvas, 2022

Connor Rothe, Low Key for comparison
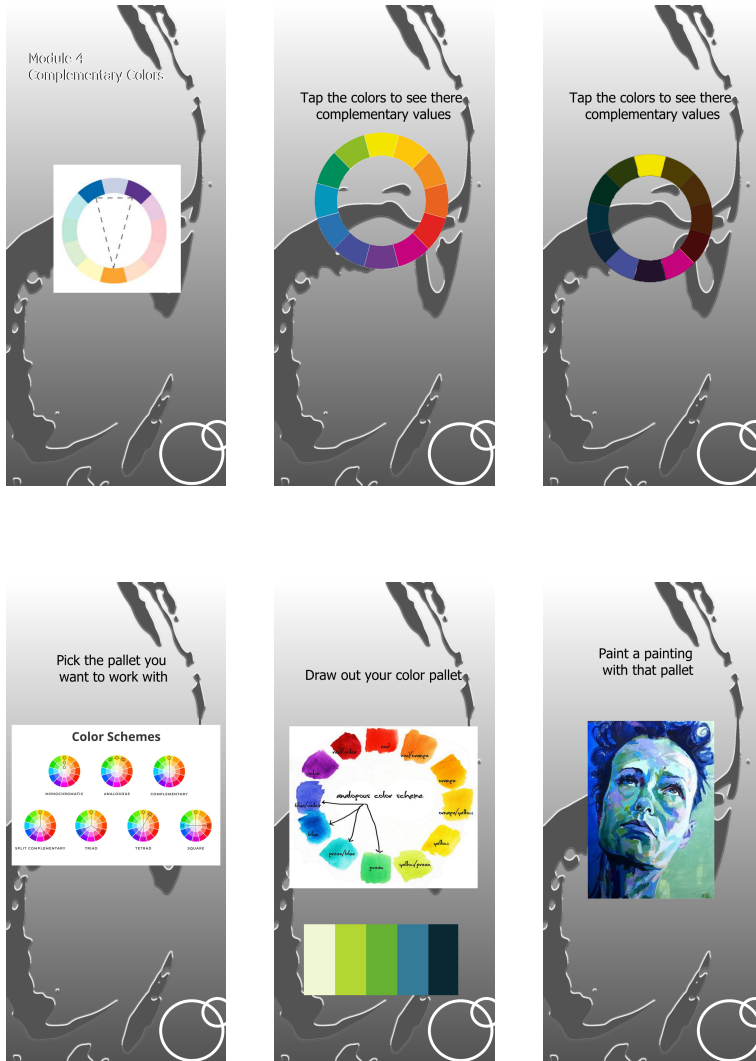
Complementary & Split Complementary Palette

Lesson Objective:

The Goal of this lesson is to present students with a color palette and have them select a set of colors to start with and show them the complementary colors palette that corresponds to those choices. This will allow them to play with colour and understand the ideas of complementarity.

Lesson Details:

Students will choose and explore the ideas of complementary colours and be able to select a colour scheme to explore. They will then be prompted to create a colour palette with paint with the shown scheme on the screen for comparison. The students will then be prompted to paint a painting of the subject of their choice with this colour scheme and be given the opportunity to take a picture and have the app generate a colour palette of the painting to see how close the came to their original goal.

Storyboard:

Module 4
Complementary Colors

Tap the colors to see there
complementary values

Tap the colors to see there
complementary values

Pick the pallet you
want to work with

Color Schemes

Draw out your color pallet

Paint a painting
with that pallet

First the student draws their initial sketch and begins by taking a picture of their drawing with the XRAS app
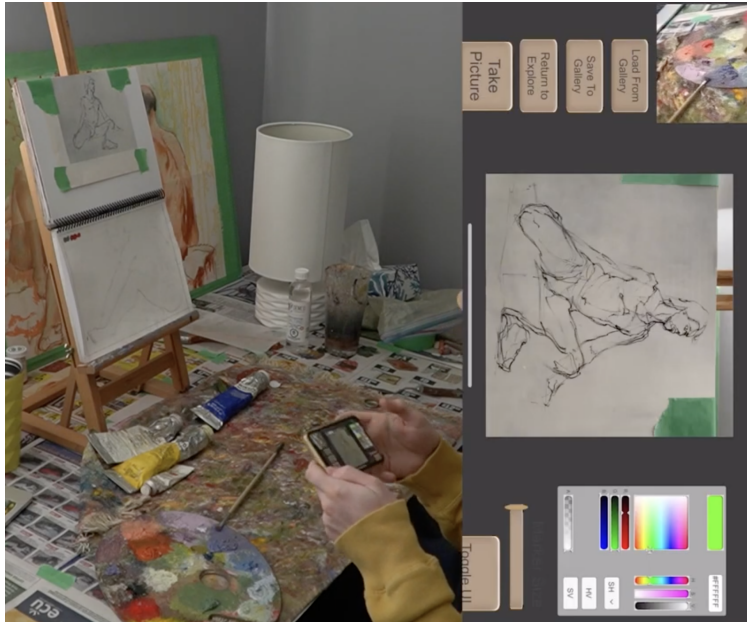
Next, the student augments by drawing lines to indicate proportion to help them with their painting and they begin painting using this to inform and guide them.

The student wishes to test out ideas for complementary colours and drawing in various tests for highlights using the app:
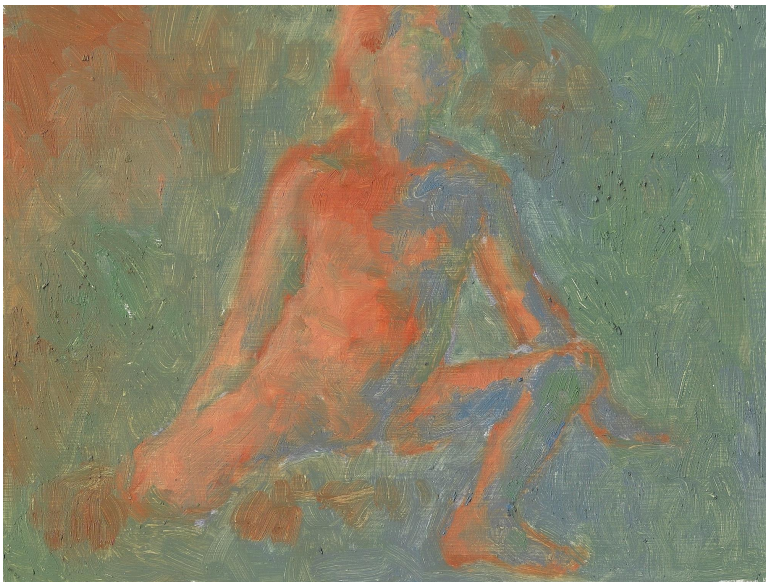
After choosing which direction they wish to pursue, the student continues and completes their painting using these guides as reference.

Final Painting Example Using XRAS Tutorial Guide:

Connor Rothe, Split Complementary Theory, Oil on Canvas, 2022

Connor Rother, Complementary Theory, Oil on Canvas, 2022

Ethan Platt, Split Complementary, oil on canvas, 2022

How to obtain and compile the XRAS application:

The Codebase

The complete codebase for the XRAS can be found here
https://github.com/syberspaz/AR_PaintingApp
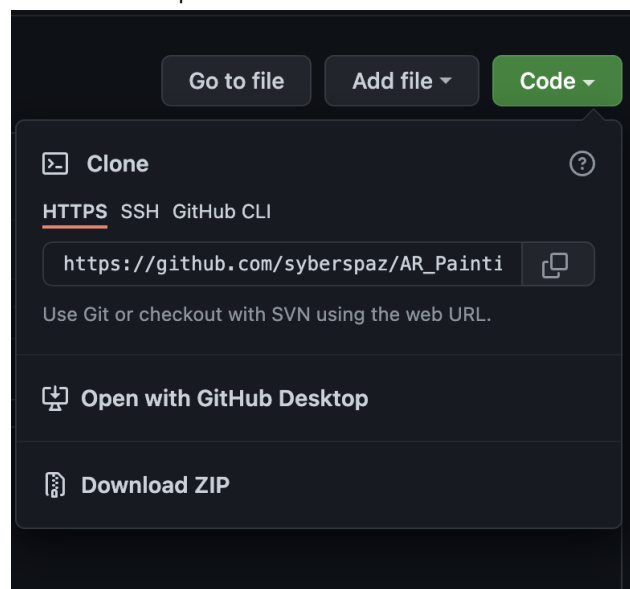
System Requirements

Platform: Mac OSX
Engine: Unity 3D
Pre-requisites:
- Software:
  - Unity3D - 2020.3.31f1 LTS (tested on this version)
  - Xcode
- Hardware:
  - iPhone 11+ or iPad
    - OS 15 or higher (tested on OS 15)
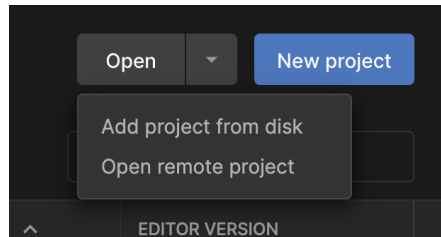- Apple ID (free)

Building the XRAS:

1. Download the code from the github by either cloning the repository or clicking on Code->Download Zip

- This will download the entire codebase to your mac, unzip this and place the directory wherever you would like on your computer

2. Open Unity Hub
   ○ Select the Dropdown beside "Open" and "Add project from disk"

   ○ Select the inner directory in the codebase called: "AR_PainitingApp_UnityProj"
3. Open the project in Unity
   ○ You may have to change the project to use the version of unity you have installed but any 2020.3 version should work
   ○ In Build Settings switch to the IOS Platform
      ■ This will take a while
   ○ Click "Build"
      ■ Create a folder on your drive to put the build, I called it 'xras-build'
      ■ Select this folder
      ■ Wait as Unity builds the XCode project
      ■ When complete you will be notified that it is ready (shouldn't take too long)

- ■ Inside the build folder you will see:
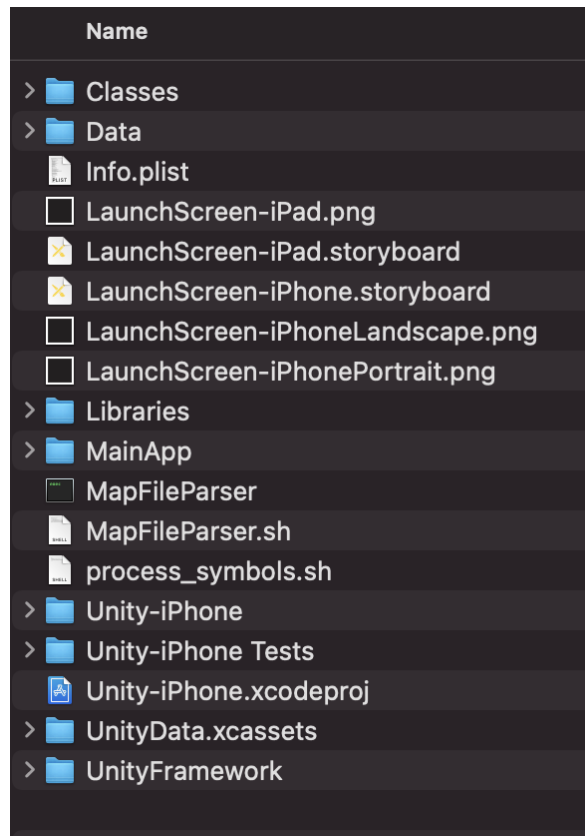
- ● Double click on the .xcodeproj file to open in XCode
4. Configuring XCode
    - ○ Once the project is open you need to configure xcode to build for your device
    - ○ First step is to connect your device to your mac (if this is the first time you connect, you will be asked to trust your mac)
    - ○ In XCode, click on the "Unity-iPhone" project on the left panel and in the top where it says "Unity-iPhone" click it and select your iOS device that you have connected, in my case I have connected "Andrew's iPhone"
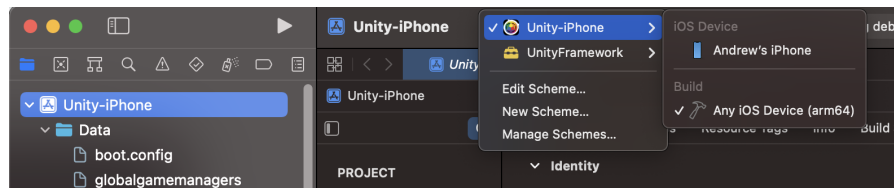

    - ○ Now, select "Signing & Capabilities"
    - ○ Select "Automatically manage signing" and a popup will appear, click the "Enable Automatic" button:
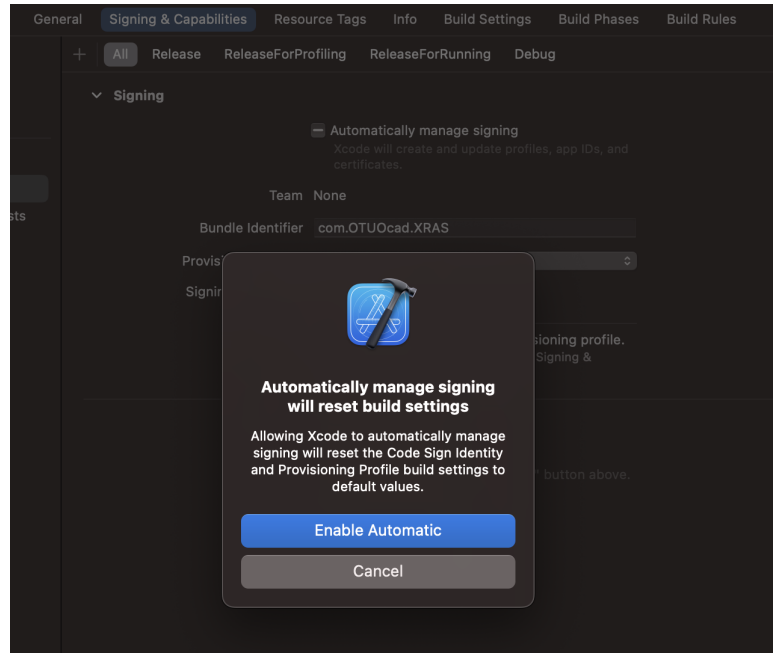
- Click add account and log in with your apple id
- Now ensure that you have a "team" selected
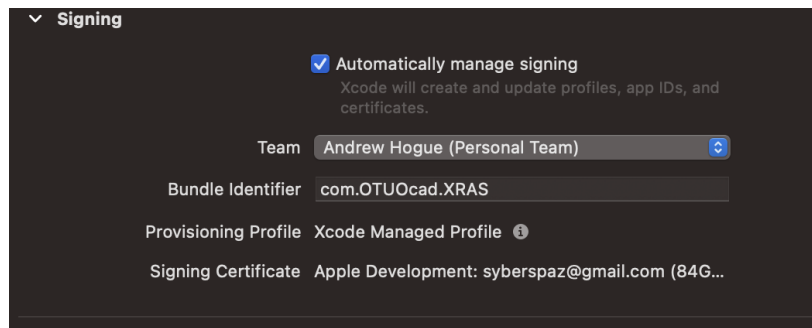
- Press the Play button to build
- Note: because of the way Apple development works, the app will build and then deploy to your phone, however it will fail the first time
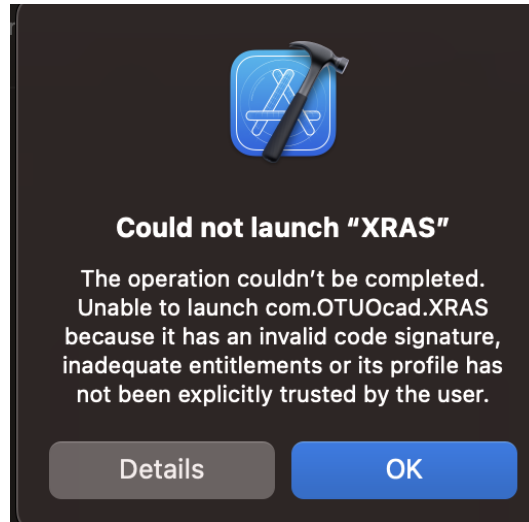
- This is perfectly normal. You must go into Settings->General->VPN & Device Management->Apple Development: <your appleid>
- Then select trust, the process should look like the screenshots below (FIGURE-iPhone Trust)
- In Xcode, select the Play button again and it will now deploy to your phone
- At this point you should now have the XRAS icon on your iPad which looks like:

- Now you can select and launch the app.

FIGURE-iPhone Trust: Setting the trust settings on your phone for development