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**Final Report**

# Early Years Education

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## Abstract

Due to the rise of COVID-19 and social distancing within schools, Early Years (KS1) have suffered a lack of hands-on teaching when it comes to learning content, such as the alphabet and other basic drawing/writing skills. My proposal was a mobile application that will allow children to learn and practice such skills. This involved application development as well as research into how exactly the skills that a teacher can provide can be transferred into the application to provide a positive experience for the user. My proposal is that by using a touch screen to learn how the letters are drawn they can then transfer that to using a pencil as it is a similar movement pattern. I researched and adapted an activity within a delivery method of education called the “Montessori Method” to gauge the usability of remote learning applications to promote literacy improvements in ages three to seven. Based on the report it was ascertained as to whether a more prolonged test into this area should be created using my application. Initial testing results showed promising results in improving the literacy abilities of adults and demonstrate that a prolonged test should be considered to research into beneficial results within children.

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## Introduction

Due to the rise of COVID-19 and social distancing within schools, Early Years (KS1) between the ages of three to seven have suffered a lack of hands-on teaching when it comes to learning content such as the alphabet and other basic drawing/writing skills. These skills are important as they are a natural progression in the child's education and are key in providing the first step into their literary education so having that affected by a pandemic is an issue that needs to be solved.

The proposal is a mobile application that will allow children to learn and practice such skills. Researching into the topic found a teaching technique for those with learning difficulties and others who are simply struggling with their development called the "Montessori Method". Part of the method involves drawing the shapes of the alphabet in sandpaper, allowing them to learn the "feel" of the word, so that when they come to writing the character, they can draw the letter on their paper with their finger beforehand to remind themselves about the shape of the letter (Gruenberg, 1912).

The technique has potential to be adapted to no longer need the sand, as the main aim of the technique is to learn the shape from your finger moving, so a positive reinforcement system on a mobile application where they would trace using the touchscreen should allow the transfer of those kinaesthetic skills allowing the user to develop and grow at their own pace. This will allow part of the activity to be transferred to the children and it will allow for the easy remote teaching of the alphabet, both during the pandemic, and afterwards when in person teaching is resumed.

Research was carried out into the various algorithms and methods that could be used to implement the comparison of the data, as well as the Framework to be used to develop the application. The framework comparisons concluded on Kivy as the choice, with MSE being used as the comparison algorithm, also known as Mean Squared Error (Kivy.org, 2021).

Discussion of the benefits of Kivy compared to other Frameworks is carried out, as well as the design and implementation of the application, issues that occurred during the completion of the application and how the usability of the application fared (Kivy.org, 2021).

Due to the timeframe set, only a short amount of testing on an older age range than desired is present, to test the usability of the application. Further trialling will be needed over a longer period of time to see whether the application is truly beneficial for the Education Sector. However, from the opinions of the testers, a base understanding is gained of how well the application seems to suit a wider audience, as well as their stipulations into whether it would be useful for younger ages.

## Background

The issue first came to light when the pandemic hit the United Kingdom, as I have family members working in primary education. They explained how their colleagues teaching children were particularly struggling with supervising the development of the alphabet, and how during lockdown it was hard to have one to one supervision with development. After noticing the extreme success of applications like Zoom where according to the BBC “Use of the firm’s software jumped 30-fold in April” (BBC, 2020) as they discuss the success of the application during the pandemic. From this massive rise in remote forms of work, consideration was taking in that a remote form of delivering education would allow for a new way of developing children’s education.

Despite progress with managing the impact of the pandemic, with the vaccines seeming to be successful, the use of remote applications will still prove to be useful when communicating and working with others. Applications that allow for remote learning are likely to be successful, as it means that the education sector can continue at the same rate even if something unforeseen occurs such as another pandemic.

After determining that an alphabet application would be beneficial, Research began of techniques for teaching the alphabet. the majority of education was primarily kinaesthetic, with examples such as early years education tracing the letters on paper. While the majority of the research into these methods proved that although they were appropriate for children with a starting competency in the alphabet, the association between the shape and what it represented for those who did not have that competency, or those with learning difficulties proved especially challenging (Clues to Dyslexia in Early Childhood, 2021). This brought forward the realisation that even though every child must be struggling with education during the pandemic, those with learning disabilities must be experiencing even more difficulty as the remote form of learning does not lend itself to the one-on-one support that can be a necessity for those with disabilities.

Researching into forms of education delivery specifically designed for those suffering from learning disabilities, A method of delivery emerged that seemed to support the hypothesis of the project. This method of teaching involved a very kinaesthetic form of learning called the “Montessori Method” (Gruenberg, 1912).

### The Montessori Method

The Montessori Method was first developed in 1907 by Italian researcher Maria Montessori as a way of building education for children more naturally (Lillard,2013). This approach started to gain mass attention in the 1960s when she released further publications on the method, which encouraged other researchers such as Joseph Hunt in 1968, to publish their own research into the topic of this form of educational delivery. Research into the method is still being investigated, with papers such as “The Early Years: Evaluating Montessori Education” by Angeline Lillard in 2006 still discussing the now over 100-year-old method, and still discussing its benefits as well as how the method has been modernised and adapted over time (Lillard, 2006).

Further research into this form of education delivery does bring up some issues as a lot of the papers must be considered a product of their time, as the wording regarding those with special education needs would not be considered appropriate nowadays such as in Pickering’s paper “Successful Application of Montessori Methods With Children At Risk For Learning Disabilities” (Pickering, 1992). However, from further reading into these papers, there appears to be no malice in these words. Instead they were simply using the terminology of the time, and the methods were developed with the aim of a positive outcome for those using them.

The method is divided into 5 main sections, involving several activities per section. Research began into the methods and regarding each set of these activities that they contain. One of these activities seems to refer to the a relevant approach to the problem presented: the “Sandpaper Letters”.

### Sandpaper Letters

With this method, Montessori hypothesised that writing comes before the use of reading, as when the child would try and read, there could be issues when discerning a letter. If the child became confused about a certain letter, they could write the letter instead to understand what the shape was as it had been imprinted into their muscle memory which would give them a greater chance of understanding (Pickering, 1992). The original method involved the learner tracing their finger on cards with letters created with glued sand, similar to the texture of rough sandpaper. As the learner traced the letter, they would speak the sound of the letter, allowing for a multisensory approach to learning, giving a greater chance of retention. This original method was then adapted into a more modern form which involves a two-step process, where the learner would be presented with a tray of sand, with either the instructor working in the same tray, or for an easier understanding of the method, their own tray of sand. The instructor would present a piece of card with the shape of a letter for example “L” in sand glued on. The child would then trace the letter on the card to get the “feel” of the shape, with the child being asked to repeat the sound of the letter to allow for visual, auditory, and kinaesthetic learning to all be achieved in one fluid motion. The learner would then try and trace the same letter into their tray of sand to see if they can replicate the shape of the letter. The instructor would trace at the same time in their own tray so that the child could visually see whether the letter matched, allowing them to easily understand that with positive reinforcement that they were following the correct shape (Sandpaper Letters - Refresh Your Presentations - Montessori Services, 2021).

This approach would then continue with other letters for a small amount of time, at which point a new activity would commence, to ensure the learner stayed engaged. Over a set time period, such as twice a week for a month, the task would be repeated and the learner would begin to learn in their muscle memory at a semi-rapid rate the shape of the letters, allowing them to recognise the shape of the letter when reading as they would trace the shape when confused.

This activity does seem to match an adaptable solution to the problem proposed, as the use of kinaesthetic learning would be similar to the method of delivery proposed. This is due to it allowing for the child to use a touchscreen instead of sandpaper to learn the shape of the letter, with instant gratification on successful completion. The auditory element would also be key if the project was to follow the Montessori Method exactly, but the kinaesthetic side of the method would still provide a positive learning experience. While this is not a direct tool of learning, this would be beneficial as a supplemental program to the teaching already provided.

### Use of this Method Already in Technology

Looking into whether this solution has already been created with the “Montessori Method” in mind is crucial to understand whether this project is necessary to continue. Applications involving different sections of the “Montessori Method” can be disregarded as the application development would involve only adapting the “Sandpaper Letters” section of the Method. This is due to it being the closest relation to the problem proposed, as other activities involved more complex literacy learning such as learning words. Online research established that there were several sites displaying applications that had been developed with the “Montessori Method” in mind. While other sites did display relevant applications, they appeared to demonstrate what certain Montessori schools would provide following enrolment, such as the site from Northwest Montessori Preschool would provide



(Northwest Montessori Preschool, 2021). Although this provided useful knowledge about the viability of the proposed application, due to the restricted access to existing applications, the application would remain valid as a learning experience for everyone, not restricted to fee paying institutions. As mentioned previously, several sites did mention applications that could be downloaded, and I will discuss one of the sites: “Mobile Montessori” (Mobile Montessori, 2021).

After reviewing the applications that “Mobile Montessori” provides, the closest activity to the proposed application was the “Alphabet” application. The user is required to drag letter tiles to the correct spacings, an approach that is different enough from the application proposal that within Montessori specific applications, the project remained unique (Mobile Montessori, 2021).

The next stage of research involved a review of Montessori specific applications on the Google Play Store. “Montessori Preschool” is an application that appeared to follow a similar method, therefore it would be important to assess if this application was a valid competitor product. A practical review of the application identified that it had a confusing UI and navigation approach that caused delays when locating activities that matched the application proposal. Scrolling the main activities shown uncovered the activity “Sandbox”, seemingly similar to the more modern version of the “Sandpaper Letters” activity, as well as the application providing their own form of the “Sandpaper Letters” activity (Montessori Preschool, 2021).

When reviewing the “Sandbox” activity, The Capital Letters and Cursive Letters activities were locked, so proceeded with the lower-case option. The application would auditorily identify the letter you wished to draw, then allowed the user to draw in an unrestricted manner before simply exiting the activity. The lack of positive or negative feedback to the user resulted in the exercise having more in common with a simple drawing application. The proposal is sufficiently different from this activity, due to it assessing accuracy and providing feedback to the user (Montessori Preschool, 2021).

When researching the one remaining related activity “Sandpaper Letters” this exercise was restricted by a paywall requiring an annual £44.99 subscription to activate. Unwilling to pay this price to simply test the application for similarities, the preview images provided did suggest similarities to the proposed application. However, the paywall restriction to access the application highlighted a key point regarding affordability. Schools might be unwilling to pay for a year of teaching for this application, as it would be multiple classes containing multiple pupils all requiring that £44.99 to be paid, and parents would not be happy if this payment were instead forced upon them instead by the school. The application was very generic, focusing on a large quantity of activities, rather than specialising in one specific activity. This does have its benefits as it means if you do pay you get more pecuniary value. However, when it comes to learning tools children can be easily distracted, so having an application such as the one proposed can ensure that they do not run the wrong activity and the teacher knows exactly the navigation needed, as confusion ensued when the application was initially used trying to find the relevant activities. These differences cemented that the proposed application was to be considered unique enough compared to Montessori Method specific applications, so it was then time to consider the application within the realm of applications in general (Montessori Preschool, 2021).

### Other Applications and Market Research

Research then began into the market appeal of the application. If there were no applications that were similar that did not reference the Montessori Method, that could indicate either the method could be unsuccessful as a method of delivery, or that it was an unpopular method of delivery instead.

In contrast, if the market were saturated with similar applications, it would at least have the positive effect that the method is used and is popular. However, it was required to ensure that the application was coming from a different approach instead to make it unique enough to be wanted.

Research began by using the Google Play Store search function with the phrase “Alphabet Tracing” as that was the main principle of the application. This came up with several results, and the market did indeed look saturated to begin with, requiring further research into how the application could be different. Looking into these applications and trialling them out, a common theme occurred within the vast majority of them, they all had a very distracting format. Everything was either animated, contained bright colours or using sounds to encourage the child with one even using an animated dog to watch the user’s finger movement.

The majority of the apps used heavily limited where the user was able to draw, only being able to draw within the shapes that the app specified, with one application allowing to “paint” the entire screen and because the shape had been filled in doing so, it was deemed correct. This was an obvious difference to the hypothesis where it specified that tracing letters would cause muscle memory to learn the alphabet, instead this considered only seeing the correct shape would cause learning to form instead. Thinking about the restrictive nature of these applications, as well as the chaotic nature of the application related back to the research of the Montessori Method, about how they discussed a controlled environment.

According to Kingsley Montessori School, the controlled environment as Montessori stated was the location that the child interacted with the activities, where the main principles of the controlled environment are (Lacroix, 2021):

- Freedom
- Structure
- Order
- Beauty
- Nature
- Reality

In practice, this is hard to understand. An article called “The Prepared Environment” describes the process differently. It stated that the environment should allow the child “independent learning”, where freedom would be considered the most important part of the principles. Due to the restrictiveness of some of these applications, if the user is allowed to have a slight freedom within the application, especially when it comes to the drawing side this will further develop the specifics of the Montessori Method and hopefully provide a more independent form of learning (Lacroix, 2021).

The article also stated that the “Beauty” of the environment should “strive to deliver a calming beauty” (Lacroix, 2021). In using the applications, some of the applications could be considered too “busy” or “chaotic” and could cause the user to instead lose focus on the task at hand, reducing the chance for muscle memory to occur, causing a decrease in the effectiveness of the application. By creating a calm and less cluttered environment for the application, it will help provide a different enough structure for it to be considered valid.

### Validity of the Application

After presenting research into the market appeal of an applications similar to the proposal, the design of the application would provide a unique style that the competitors experienced do not provide. This allows for a calm learning format, that teachers would be able to easily work into their teaching schedules. The freedom of the application will also allow for the “Montessori Method” to be successfully taught. Unfortunately, due to the time constraints within the project, it would be improbable to build the application in time for a sustained period of testing. This makes it unable to see if the application provided an improvement in literacy abilities compared to conventional methods of teaching. With the lack of multisensory methods of delivery that the Montessori Methods provide, the application will be useful, however could not be compared fully to the activities that the “Montessori Method” suggests. This application could be suitable as a supplement to conventional teaching, where it could be used as a teaching tool within classes to allow for a more modern form of learning the alphabet or as a homework tool to allow the students to practice their alphabet at home. This is also beneficial as if for some reason remote learning was continued, it is a way of guaranteeing a small level of the same type of teaching that would occur.

In the approach, these conditions need to be followed up, whilst also considering whether a multisensory form of learning would be possible in the timeframe, or whether given more time, this method would be able to be achieved.

### Conclusion of Research

From the research, the application is indeed unique enough to be further developed in both design and implementation. This would allow, with prolonged testing outside of the project timeframe, whether the application would prove to be a useful supplement to the current form of teaching. This could then be used for those remote learning as well as those who are experiencing in person teaching. The application must ensure that the user is in a calm environment and is able to have as much freedom within the confines of the applications as they can. If this is achieved then it could be considered a sub-goal application of the “Montessori Method”. Additionally, to ensure that the application is different from other applications, as well as following the “Montessori Method”, it must make sure that the application would be considered non-cluttered and open ensuring that their focus would not be drawn to too many other objects that were not relevant to the success of the muscle memory retention.

## Approach

After Researching was complete as to whether the idea was a viable solution to the problem, it then became clear to work out how viable the solution would be to create. The first step was to investigate mobile development in various coding languages, and came across the most popular choice for android development, Android Studio. This presented issues, as the technical specifications for coding in Android Studio are quite high and can cause some computers to overheat. As the project would primarily be using a low specification computer to code and compile, a coding platform needed to be found for mobile development that was lightweight and preferably in a language previously explored (Android Developers, 2021).

Deciding to narrow down the search to coding languages used in previous projects, Python was chosen over Java due to more experience in the language (Python.org, 2021) (Java SE Development Kit, 2021). This narrowed choices on coding frameworks significantly as for Android and IOS Development, there are few applications or frameworks that support Python as the coding language.

## Framework Comparison

The first framework was BeeWare (BeeWare.org, 2021), a framework that seemed to be simple for cross platforms applications, however in practicality it seemed quite complicated. This is what lead to Kivy (Kivy.org, 2021). This framework was primarily for Android development, with it being able to run on IOS with some further development. This was fine for development as the application would be tested on an Android device so running through this framework was achievable.

### Kivy vs BeeWare

Researching further into the BeeWare framework, it seemed useful for very generic projects that did not require a lot of specific details. It also did not allow easily for a custom UI, instead only allowing for the user to use the native Android or IOS interface. The main appeal of the framework was the easy conversion to Android for devices on Windows, and as discussed later on in the project, this proved to be a very useful feature that in retrospect was overlooked (BeeWare.org, 2021). In comparison, the community projects listed for Kivy seemed like they were built for much more specific aims and given the nature of the application, it was the choice to make. Kivy, unlike BeeWare, allows for the creation of custom UIs for the application. This suited the project as it allowed for a UI more suited for a child to be made as opposed to following the standard look. The main issue with Kivy in retrospect is the fact that you require Linux to convert the application to Android, something that was not made very clear with the documentation they provided. As several devices would be used to code on this project, something that was less intensive on the computer would be necessary. Looking at the standard requirements that most people work on, Kivy is the preferred choice, so it would require a dual boot OS to be installed on a device to allow for the conversion to Android (BeeWare, 2021) (Kivy.org, 2021) (Kivy: Cross-platform Python Framework for NUI, 2021) (dbader.org, 2021).

## The Decision

Evaluating the positives and negatives of the two frameworks, Kivy was the preferable choice of framework, as the custom UI allowed for a greater control over the application allowing the tailoring of the application to a particular audience (Kivy.org, 2021). It was also the more lightweight framework in terms of system requirements which gave it the edge in over BeeWare (BeeWare.org, 2021). Now that a framework had been decided, further research was required into the Kivy framework to decide whether it was a valid form of delivery.

## A Further Look into Kivy

Kivy is a python-based Framework that runs with a 'Builder' string or file similar to a CSS file in HTML (HTML Standard, 2021). Kivy can be run with only the python file however to use the full extent of the application and allow you to fully edit the application easily, the hybrid use of both files is necessary. The file type unique, called a ".Kv" file (Kivy.org, 2021). To ensure that the implementation side of the project would not come under any unnecessary delays, experience in this form of coding was required using the "Pong" tutorial shown on the frameworks website (Pong Game Tutorial — Kivy 2.0.0 documentation, 2021).

In doing so the benefit was shown with not using the ".Kv" file, as using the python file only commands are different than the hybrid use, following a similar manner to a library within Python: "Tkinter" (tkinter — Python interface to Tcl/Tk — Python 3.9.5 documentation, 2021). This was a useful introduction into the framework, where it allowed for learning in a way that was still familiar. However, running through the tutorial, the code was centred around the principle of the Builder file. Certain sections of the custom UI were being omitted, whether due to the simplicity of the tutorial, or due to the fact that without the Builder file, it could not be achieved. The end of the tutorial explained how important this hybrid way of coding the file allowed for greater control over the front-end of the application and how it interacted with the rest of the application (Pong Game Tutorial — Kivy 2.0.0 documentation, 2021). This required further research of how the builder file would work. Research began in the documentation site about the Builder file and how it affects applications, specifically mobile applications. An issue emerged in this research as the framework can be used for desktop development so notes were made about how to ensure that the application was tailored to the mobile side of development (Kv language — Kivy 2.0.0 documentation, 2021).

### Issues and Resolution Within Kivy

One of the two issues required to be researched before Kivy could be chosen was whether the code could run other libraries explicitly imported. Looking at the Kivy Framework resources, there was no easy way of importing test images for the project, so research began and a library was found that allows for the importing and comparing of images called “CV2” that will be discussed in further detail later (opencv-python, 2021). Researching into the framework, it was more difficult to compile the application to Android at the end with external libraries, as each library would have to be written to the compiler’s text file to ensure inclusion. However, it was possible to put other libraries into the code and use them within procedures and functions (Create a package for Android — Kivy 2.0.0 documentation, 2021).

The final issue was whether the framework itself could be used for graphical use, as when drawing with coding languages, comparisons could be drawn to the mathematical program “MATLAB”. In this program the system keeps track of the coordinates and “paints” between those coordinates (www.mathworks.com, n.d.). Looking into the framework there was indeed a “canvas” part of the code that allowed for a similar method to be used and although it was difficult to do, it was possible to save this canvas for use when necessary (Canvas — Kivy 2.0.0 documentation, 2021). This was important as if the users wished to see their previous progress with the application in the future, digital copies of their work would be required.

### Framework Packages

Researching the graphical side of Kivy expanded that within the Framework there are several packages when installing, with the most common installed being the Base, but the other options also include (Installing Kivy — Kivy 2.0.0 documentation, 2021):

- Media
- Full
- Dev
- Tuio

It was then required to review each package, to conclude if there was a specific package that would suit the development of the application. Doing so through the process of elimination produced the result that there was one package that indeed suited the problem.

The “Base” package, although commonly installed, does not allow for audio and video, and due to the possible use of audio with the application it was eliminated. The “Tuio” package is only necessary if you wish to run applications that track multiple real world objects on a touch screen. “Media” was also disregarded as if I am wanting to develop the extended toolkit, “Media” only contains media tools to work with such as methods to view photos and videos, similar to a gallery application. So given that I will be using graphical and possibly statistical tools as well, “Media” could not be used (Installing Kivy — Kivy 2.0.0 documentation, 2021).

This left the “Full” package of Kivy as the documentation was unclear about what the “dev” mode contained, and from what could be gleaned from the information, seemed to lack the basic functions that the other packages contained. Even if the development software was a little more bloated with extra functionality than necessary, it was still within the boundaries set for the system requirements (Installing Kivy — Kivy 2.0.0 documentation, 2021).

## Conclusion of Framework Comparison

After researching and coming to the conclusions about these two issues, Kivy was in fact an apt framework for development of the code due to the ability to allow users to create custom drawings within the application, as well as allowing the use of external libraries. This framework was also low in terms of system requirements, making it useful for working on multiple devices, as would occur during this project.

## External Libraries

After comparing the framework, it now came to researching how the application would work. This led to further research something briefly seen before when looking for external libraries for Kivy, the library called “CV2” (opencv-python, 2021). When researching initially into the topic, the library allows for the comparison of images, and as mentioned in the initial plan, direct comparison of the shape of the letter was desired. However, in practice this was a much more complicated problem that was improbable to be completed in the allotted timeframe. Instead, if the canvas, or at least the saved image of the canvas was converted to the same size as the test data, image matching could be used, where differences in the entire images are calculated as a score. “CV2” was able to perform this resizing of the images adequately, however lacked the capability to truly compare the image, so instead a library that worked synchronously with “CV2” called “Skimage” needed to be imported (opencv-python, 2021) (scikit-image: Image processing in Python — scikit-image, 2021).

“Skimage” allows for the comparison of two images via different algorithms as long as they are the same size, so “CV2” was necessary for the main comparison. This allowed for easy resizing as it would use an image, such as the test data, as the base dimensions rather than having to specify both to the same dimensions. This was useful as it meant if one of the images was not a specific size, there would be no errors occurring. “Skimage” would then allow you to compare the images using one or both of two methods, SSIM and MSE, so it came to deciding which method would be used to compare, or if both would be used (scikit-image: Image processing in Python — scikit-image, 2021).

## MSE vs SSIM

### MSE

The Mean Squared Error, also known as MSE, or sometimes known in Statistics as Mean Squared Deviation (MSD) is a calculation to work out the average of the differences squared. It looks at a pixel in the first image and compares it to the same coordinate pixel from the second image, and works out the difference as a value, which is then squared. This is then achieved for every pixel in the images, requiring both images to be the same dimensions. Each squared difference is added to a total, with a counter running at the same time for the number of pixels compared, or more commonly the width and height dimensions are multiplied to work out the number of pixels compared. This squared total is then divided by the number of pixels to gain the Mean Squared Error, or in comparative terms, how accurate the two images are by working it out from the number of errors there are instead of working out how similar the images are. A high MSE score would be inaccurate, and in contrast a low MSE score would then be considered an accurate copy of the image. This works for what could be considered an average pixel image, as in too low of a quality image, one pixel wrong can make a huge difference in the MSE. This is less of an issue with higher quality images where the issue then becomes if there are errors in the image, they are less noticeable in the value of the MSE as there could be countless more correct pixels. So where accuracy is absolutely essential, MSE cannot be used for high quality images (Mean Squared Error: Definition and Example - Statistics How To, 2021).

## SSIM

The Structural Similarity Index Measure, also known as SSIM, is a way of measuring the similarities between two images, being an improvement of the Universal Image Quality Index. The SSIM was developed, due to the authors realising that most image quality assessment techniques rely on quantifying errors between a reference and a sample image. In essence, rather than looking whether the images are similar, as most human subjects would try and quantify, they instead would look for errors and say that how many errors that occur is how similar it is. SSIM instead uses three key factors from an image to try and work out how similar the image is. Due to the specific natures of the factors, all the images compared must first be in grayscale as colour can create a huge difference in two of the factors, however in grayscale a bright green and bright red would appear similar. The three key factors are as follows (Wang et al, 2005):

- Luminance
- Contrast
- Structure

The algorithm works out the luminance and contrast value and uses that to work out the structure comparison, and compares the luminance and contrast values individually to form a score between -1 and 1, where -1 would be considered not a match at all and 1 would be considered a perfect match (Wang et al, 2005).

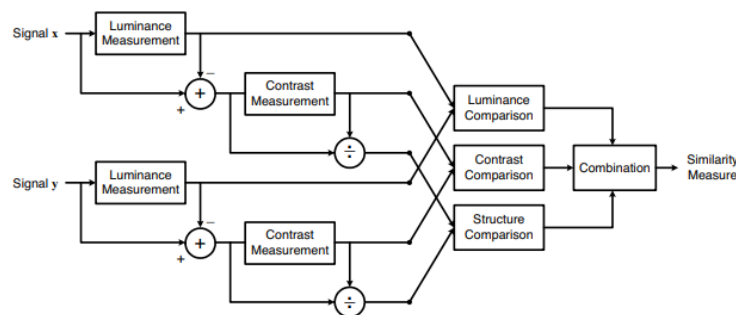


Fig. Flow Diagram the original Creators of the SSIM algorithm made. (Wang et al, 2005)



### Comparing the Two Algorithms

Due to the test data, as well as the user data containing a lot of alpha pixels, the SSIM algorithm is automatically going to have a high similarity score. However, due to the score being usually to several decimal points, it allows for accurate decisions as to what would be considered a pass and what would be considered a failure (Wang et al, 2005).

MSE is typically given to a more variable set of decimal points and would consider a lot of the pixels similar so again the MSE score would be low, meaning the check would be harder to run. However due to it using pixel difference, as opposed to the overall difference, it might be more useful but requires further research.

During research into the comparison of the two algorithms, an article emerged about how MSE can actually cause issues when SSIM does not, however in specific cases, as discussed in “How-To: Python Compare Two Images”. When comparing the same set of data in this article, the score given for MSE was 0 as expected, and the SSIM giving an accurate score of 1.00 (Rosebrock, 2021).



Fig. Comparing the two original images together. (Rosebrock, 2021)

When the test data was then compared against a different grayscale effect on the same image, the MSE gave a much higher score of 1401, and the SSIM score was reduced to 0.78. Both algorithms appear to be viable solutions; however, unexpected results occur from the third test (Rosebrock, 2021).



Fig. Comparing the Original and the Contrast adjusted image (Rosebrock,2021)

The second comparing image (the third in total including the test image) was not the same image, instead having an image placed on top of the original test image before having the greyscale effect used to the same extent as the test image. The results then proved interesting, although the SSIM score had gone down, now to 0.69, as the image was different, due to the greyscale effect being the same, the MSE score had gone down to 1076, saying that this image that, to the eye, was more unique than the previous test was more accurate despite being clearly wrong. (Rosebrock,2021)

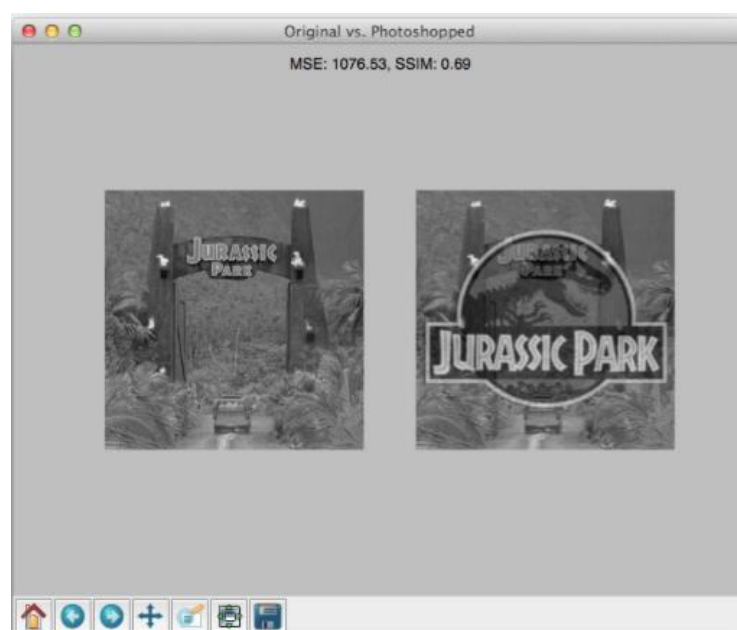


Fig. Comparing the Original and Photoshopped overlay image (Rosebrock,2021)

This shows the main issue that arises with MSE is in photoshopping images or to be specific, superimposing images over the base and giving the same greyscale effect. When imposing an image on top of the base image that runs a similar colour scheme, there can be an inaccurate depiction of the accuracy of the image as some of the pixels might match even though from a visual look the comparison is clearly wrong. This issue does not occur with SSIM and is why it is commonly chosen over MSE when it comes to image comparison of complex images (Rosebrock,2021). However, due to the fact that nothing within the data used could skew MSE, such as photoshopping will occur, it is safe to use either.

### Conclusion of Comparison Algorithm

After careful consideration and looking at both the pros and the cons of each form of image matching, MSE was decided to be the superior algorithm for the project. This is because it allows the user to accurately figure out the differences in the two images. This is better than working out the overall composure of the image as a pure black and white image like the ones suggested could cause issues with SSIM. However, a form of failsafe was required to be in place, to ensure that it would keep it as accurate as possible. The first form was to make sure that the test data would be the exact same colour as the user's data, to ensure that that the MSE error would not be because the colour is different, and instead would focus on the user's work. Font size is also important in this regard, or rather making sure the user is only able to draw the same pixel width that the test data contains. Due to MSE checking every pixel for difference, care was needed to make sure that the user can gain the greatest understanding of how accurate they are being with their submission.

### Font

This then raised another issue as the font for the test data would be crucial for the age of the user, as well as the usability of the application. Using too complex a font would mean it would be difficult to ensure accuracy on something like a touchscreen. This also would confuse the age range this application was being designed for, as they would be wanting to practice as simple a character to guarantee further development to be possible.

Use of the correct size of font was crucial as well, as too small of a font width would make the shape too difficult to trace accurately for the user. The opposite issue can occur as well, where the font width could be too large for the screen, turning the shape unclear, causing issues with the user trying to follow the aim of the application by learning the muscle memory of the shape.

## Design Documentation

### Image Matching Window

The application design process started with the most important part of the application, the image matching screen itself. The design of the application screen required that there were three functional requirements elements:

- The painting window itself.
- A button to clear your progress so far in case you have made a mistake.
- A button to submit your drawing to allow for the comparison only when you are ready.

The final button would be needed, as it allows for as many strokes as the person wants before submitting. After deciding these points to be what would be displayed on the screen, I came up with the following rough sketch:

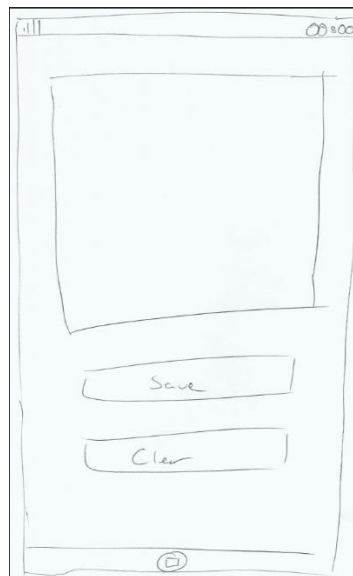


Fig. Shows the Initial Sketch for the Application Screen.

This rough guide allowed for a more accurate design to be implemented, allowing for the following figure:



Fig. Shows the Digital Sketch made from the rough sketch design.

## Popup Window

After designs for the drawing window was produced, it seemed apt to design some form of popup to appear allowing for positive reinforcement if the user had got the match correct. This would also act as a form of consolidation if the user had not managed to match the letter. Consolidation was chosen to ensure that a positive approach was followed throughout the application.

Deciding how the popup would look for the passing popup, as the failure popup would be quite similar, the rough sketch for the popup window section was designed:

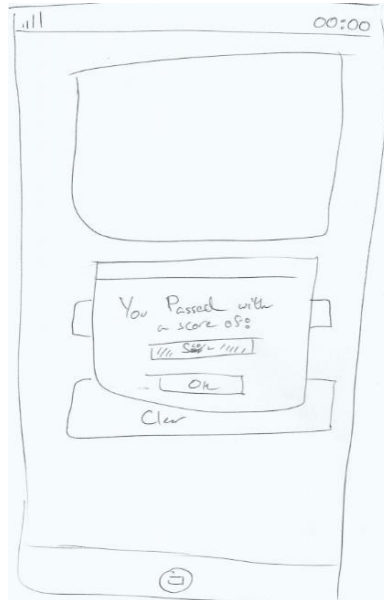
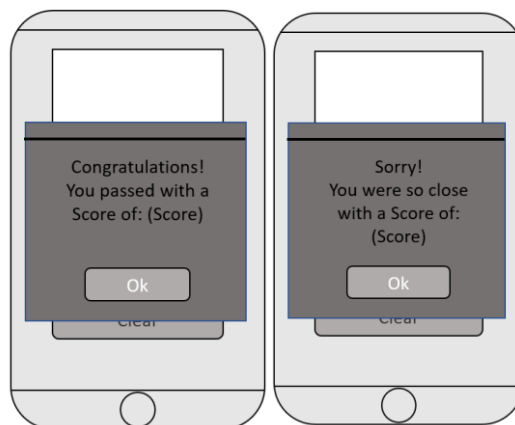


Fig. This shows the Rough Sketch of the popup window.

After beginning to digitally design the popup window, an issue emerged. The statistical element of providing the score in the design is not possible with MSE as it is very difficult to display that form of data as a percentage. This then gave the option of using the SSIM for the score, however, due to the issues with SSIM previously discussed, it was decided that instead a positive message could be shown. This also felt more appropriate for younger ages, as younger aged children would be less likely to care about how accurate they were, instead wishing for a pass/fail remark instead allowing them to know how they did. This then led to the following digital designs, a brief positive message has been included for each popup that changed by the time implementation came around:



Figs. This shows the two Digital designs for the positive and negative popups

In terms of the Image Matching Screens, all the UI elements that would be present at the time were added, and if any rogue elements that would differ from the design document did appear, they could be added as the designs themselves felt open, and not cluttered.

### Title Screen

The user would need a menu to initially greet them, so the Title Screen began to be designed. After deciding what a user would want when the application first greeted them, the following four functional requirements were created:

- A Title explaining what the application was called
- A Button to allow them to exit the application
- A Button to adjust any settings they would need to
- A Button to bring them to the drawing screen

After deciding the functional requirements, the following rough sketch was designed:



Fig. This shows the Rough Sketch for the Title Screen

This rough guide allowed the more accurate design to be digitally implemented, allowing the following figure to be created. While designing the application, it emerged that the application lacked an actual name, so after consideration was named “LetterLearn”, as it brings across a general understanding of what the application does:



Fig. This shows the Digital Design I had for the Title Screen

### Letter Screen

After designing the previous screens, the user would need some way to decide which letter they wanted to trace before it would come to the actual tracing.

Deciding that a “midway” screen with no other purpose present would allow the issue to be solved, there was no need for any other functional requirements other than the 26 buttons the user would want to press. Consideration did occur about using a dropdown menu to allow the user to choose, but instead just clicking the correct button provides a smoother user experience. This led the following rough sketch:

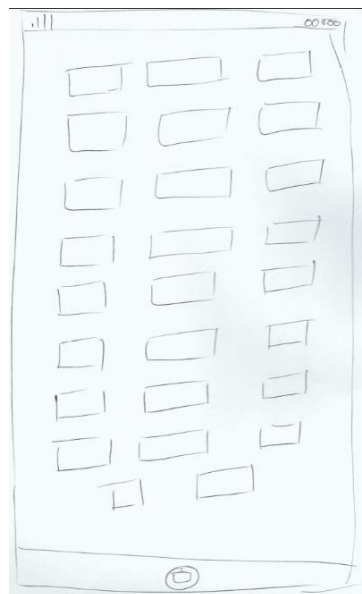


Fig. This shows the sketch about how all 26 letters would appear

Reviewing the rough guide, the screen contained too many buttons and could just make it hard to make a clear choice. Knowing this, it then allowed for refining to produce the following digital sketch:

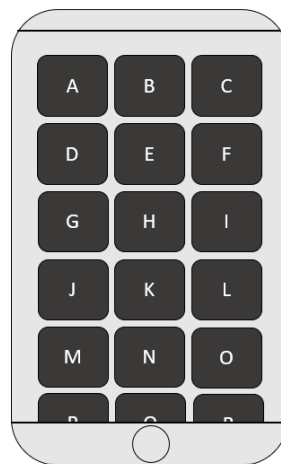


Fig. This Shows the Digital Design for the Letter Screen

This brought up the idea about using a scrolling function for the Letter Screen, something discussed further in the implementation section.

### Conclusion of Approach

Since all the screens had now been digitally designed, a clear path emerged for implementation. The application was indeed viable to create from a theory standpoint and it was now time to begin implementation. Although attempts were made to limit all the research to before coding began on the application, research into specific documentations within the Kivy Framework occurred during coding, something I did not consider before the implementation started. Although it did not prove to be an issue during coding, if a similar project was to be conducted again, deeper consideration in the design stage would be taken, as later on there is discussion about having to adjust the code at times due to a lack of research the framework specific widgets needed (Kivy.org, 2021).



## Implementation

The first step in the implementation process was to decide which sections of the code would be prioritised and which would be worked on at a later date. Due to the complexity of the matching process, the backend took the highest precedence, followed by the frontend. In retrospect, this flow of work was the right step to take, as many difficulties were encountered relating to the backend of the code.

The order in which the screens were implemented was also determined at this stage, as in the design step it was decided that multiple screens would allow for a more user-friendly application experience. Doing so provided the following steps:

1. Backend of Main Drawing Screen
2. Frontend of Main Drawing Screen
3. Backend of Letter Screen
4. Frontend of Letter Screen
5. Backend of Title Screen
6. Frontend of Title Screen

Focusing on the backend allowed a ledge to work from when focusing on the frontend that had already begun with the design documents. By having that jumping off point in the frontend it meant that a positive start with the implementation section was apparent. The Frontend of the Main Drawing Screen was worked on next as it would enable a “prototype” of sorts, allowing for subsequent progress to be easily monitored, and allowing the application to naturally expand from the completed screen.

### Backend of Main Drawing Screen

Starting with the backend, this element could then be split into several sub projects that needed to be finished before this section would be completed. The sub projects were as follows:

- Allowing the User to draw.
- Allowing the User to clear their progress.
- Allowing the User to submit their progress.
- Importing the Images.
- Using MSE to compare the Images.
- Deciding how accurate would be considered accurate.
- Making sure no data was saved.
- Getting the Application ready for the next set of drawing.

From this list there were important points that needed to be considered as they were integral to the functional requirements, and additional points that would allow for a more enjoyable application experience.

Following a review of the list, three of the sub projects were of primary and equal importance: “Allowing the User to Draw”, “Allowing the User to Submit their progress” and “Using MSE to compare the images”. This conclusion was reached as these were the three key sub projects that were integral to the achievement of allowing the user to draw with their finger and receiving feedback regarding accuracy.

### Allowing the User to Draw

Looking into the Kivy framework, the canvas widget allowed for drawing where it would mark the application as a list of points, with colour objects being assigned to it. It also provided the capability to specify which section of the “canvas” to be saved within some leniency. Instead of allowing you to decide which specific dimensions would be saved, it would work in a similar manner to an image editing program, where you could choose specific “layers” to save (Canvas — Kivy 2.0.0 documentation, 2021)(Kivy.org, 2021).

Attempting to implement the canvas code, an issue emerged. In the tutorials followed to understand the coding language, they explained how to set up screens to implement the code they were teaching. Realising a screen had yet to be set up for the application, focus was drawn to getting a blank screen to appear, so then it could be populated with the rest of the code.

```
class TestApp(App):  
    def build(self):  
        return Builder.load_file("mypaint.kv")  
  
if __name__ == '__main__':  
    TestApp().run()
```

Fig. The basic code in the python file to allow for an application to run.

This highlighted a dilemma that needed to be faced. Kivy as a framework allows for the use of a Builder string, as explained in the Approach, to allow for a greater control over the UI. However, this string can be implemented in two ways, either as a string within the python file, or instead as a separate “.Kv” file, which is then imported when you build the application.

In terms of use, the two methods act identically, but each have their own benefits. Researching into the method indicated it is slightly more efficient to use the builder string instead of the file, however that benefit is small enough that it could be considered negligible. The “.Kv” file appears to have no immediate apparent benefit, however the research established that many users of the framework used the file as it allowed them to clearly separate between the Frontend of the program (the .Kv file) and the Backend of the program (the python file). As the implementation process worked in a similar manner, mainly working on the backend first, it was decided that this would also ensure that clarity between the backend and frontend would be clear (Builder — Kivy 2.0.0 documentation, 2021) (Kivy: Cross-platform Python Framework for NUI, 2021).

To ensure a screen was able to appear the “.Kv” file was created to allow for the Frontend as well as the application to run, this then allowed for the painter to be created successfully.

```
class Painter(Widget):  
    |  
    def on_touch_down(self, touch):  
        with self.canvas:  
            Color(0,1,0, mode='rgb')  
            touch.ud['line'] = Line(points=(touch.x, touch.y), width = 30)  
    def on_touch_move(self, touch):  
        touch.ud['line'].points += [touch.x, touch.y]
```

Fig. This is showing the basic drawing code and how drawing the lines works.

To create the lines, the code had to run two Kivy specific functions (Input management — Kivy 2.0.0 documentation, 2021):

- on\_touch\_down
- on\_touch\_move

These specific commands allow the application to register any touchscreen actions, as well as allowing for the tracking of the implement on the touchscreen when it is moved. These commands are also very useful as they work with mouse clicks and movement when the click is being held, allowing to easily test the application without having to compile it every time, a feature in retrospect was incredibly useful due to the issues with compiling the application (Input management — Kivy 2.0.0 documentation, 2021).

### Allowing the User to Submit their Progress

Now that the application has the ability to draw, the first point was achieved, allowing for progression onto the next point of the three: “Allowing the User to Submit their Progress”. This point seemed very simple to implement, simply storing the image as a readable format. However, in actual practice was more complicated than it first appears.

As the way the framework stores the drawing canvas, “CV2”; the library to resize the images to ensure they were the same dimensions, would not accept the vectors, instead producing errors, explaining in the terminal that it was not an accepted format. Due to the fact that “CV2” would only accept images for resizing, research began into methods that would allow for saving the canvas such as the method “export\_to\_png”. This approach would allow the saving of the image under a name, which could then be read by “CV2”. This code was implemented into a function called “save\_canvas” as the self-documentation would allow for easy understanding in case any other developer wished to work further on the code. This presented the issue of what to name the file, to avoid confusion with any other file currently present. It was decided that due to the speed of the process between saving the file and CV2 reading the file, the current date time would work well as a way of making sure it was always the right file, as well as setting up the code ready for the future work of implementing a way that users could see their previous progress (opencv-python, 2021) (Widget class — Kivy 2.0.0 documentation, 2021).

```
def save_canvas(self):
    date_string = str(date.today())
    time = datetime.now()
    time = time.strftime("%H-%M-%S")

    filename = (date_string + ", Time " + time)

    self.export_to_png(filename + ".png", flipped = False)

    imageA = cv2.imread(filename + ".png",0)
```

Fig. This code allows for the canvas to be successfully read by “CV2”.

“Allowing the User to Submit their Progress” was now successfully completed. This would now enable progression onto the final point: “Using MSE to compare the images”.

### Using MSE to compare the Images.

As discussed in the Approach, “Skimage” was used to compare the images, as it worked dynamically with “CV2” to allow for the easy reading and comparing of the images. From the metrics library within “Skimage”, “mean\_squared\_error” was imported allowing for comparison of the images. However, another set of issues emerged: there was no test data present to compare it to, and if it was present, the images had to be the same dimensions to allow for correct comparison with “mean\_squared\_error” within “Skimage”. Research began into whether not having to resize the image was possible with only negative results appearing (opencv-python, 2021) (scikit-image: Image processing in Python — scikit-image, 2021).

The test data was required to be created to enable comparison. Using a GNU based image creation tool (GIMP), research was started into fonts that seemed close to easy handwriting. “LesliesHand”, a free font type that seemed to emulate the way that teachers would write letters for primary school children presented an ideal font for teaching how to draw (LesliesHand Font · 1001 Fonts, 2021). Using GIMP, the test data was created using “LesliesHand” font. When using the font, it became apparent that the font itself was very easy to read, whilst not feeling mechanical, a font that would be useful within the frontend of the application as well. This would also mean that the user would get to experience words written in the same font, possibly increasing the retention of how the letters should look (GIMP, 2021) (LesliesHand Font · 1001 Fonts, 2021).

Now that the test data had been created, it became apparent to import the correct test image, but as that was part of a completely different screen, for a temporary solution the code would import the “A” test data, just so that if there were any issues with the importing and resizing it would be noticed, as well as if any MSE errors occurred.

The initial plan was to resize the user’s images in relation to the test data, however when running the code later on, it became clear that the resizing was not fully working, so instead the solution involved mapping them both to 1000 pixels by 1000 pixels, to reflect the dimensions of the test data. Although it seemed redundant to resize the test data to the dimensions it already was, planning for future work as well as guaranteeing they were the same size would be essential in doing this. The MSE worked despite a large error score being present. However, for now the code was fully working, so to follow the idea of a prototype it was important that the page was fully completed in terms of backend and frontend before confronting this issue.

### Final Points of Drawing Backend

At this stage of implementation all three of the major points were now complete, allowing for the decision of the next most important part of the program. Some points had been completed in the previous sections such as “Importing the Images”. The remaining points were as follows:

- Making Sure no Data was Saved.
- Getting the Application ready for the next use

#### *Making Sure no Data was Saved*

Deciding it was logical to address these points in that order, as due to the Ethical Use submission, making sure no data was saved was vitally important to ensure that the application was still within the bounds the committee had set. Through research, it came to fruition that the “os” library in Python works well within the Kivy framework. Therefore, it was a simple job of importing the image saved, then as soon as it was imported, to delete the copy as it would no longer be needed. In the future, the data needed to be saved instead, due to another use such as User progress, it was a simple measure of removing this line of code, so due to the simplicity and efficiency of the line, the “os” library remove file code was implemented (os — Miscellaneous operating system interfaces — Python 3.9.5 documentation, 2021).

This now ensured that no data was saved, as the rest of the data such as the colour of the lines etc would be automatically deleted when the application ceased to run. This meant the point of “Making Sure no Data was Saved” was complete.

#### *Getting the Application ready for the next use*

When saving the data, the canvas that was being saved came up with an issue, it would not be removed when the save command was ran, causing an issue if you ever wanted to use the application again without restarting the application. This caused a natural flow into the frontend of the design as the design documents showed that a clear button had yet to be implemented. Although requiring the user to manually clear their drawings would be one solution to the matter, this did not seem a user-friendly solution. It was important to ensure that saving the canvas also cleared the drawings as well, so that a new submission could be run.

Research into potential solutions highlighted the “canvas.clear” command, which would wipe all of the elements related to the drawing. While initially this code was implemented successfully, in both the clear button, as well as the save command; this caused some issues later on requiring the use of the “layering” side of the canvas to solve this issue that will be discussed later on. However, for now, the method implemented worked with the application. This step concluded the Backend of the Drawing Window and the next major point could be implemented: “Frontend of the Drawing Window” (Canvas — Kivy 2.0.0 documentation, 2021).

## Frontend of the Drawing Window

Following the backend, as well as viewing the design documents, identification of the elements of the front end that were needed were produced:

- Drawing Window
- Clear Button
- Save Button
- Background Image

As the drawing window had already been completed, it was now necessary to implement the other elements. As discussed before it was decided that the Background Image would not be implemented yet, instead wanting to have one of the other screens present first before working with it, as it would allow the passing of the data required for the background image to successfully appear. This left the two button elements needed to be implemented.

### Save Button

As the most important part of the application was the submission and comparing the two images, the most important button for the user would be the save and submit button. Implementing this was quite simple, as Kivy allows you to run commands or functions depending on your need, on the Button element. To implement in the Builder file meant to follow the path in the application to the “save\_canvas” function to allow the button to run that code.

```
Button:
    size_hint: 0.2, 0.2
    text: 'Save'
    on_release: painter.save_canvas()
```

Fig. This shows the Save Button code within the “.Kv” File.

Having the button run successfully allowed the code to work the same as typing the function into the terminal. This meant the Save button was complete, allowing progression onto the next element.

### Clear Button

The clear button as previously discussed, was simple to implement. It worked in a similar manner to the save button, but instead of running a function it ran a command specifically targeted at the canvas. Once it was implemented, an issue arose where all three elements (the canvas, the save button and the clear button) were all trying to present themselves on the middle of the screen, meaning you could only access what was built last as it had the highest “order” priority.

### Solving the Order Issue

It was decided that now was the time to try and match the design documents in terms of the UI design for the screen. Through research, it became clear that Kivy has a number of “layouts” able to be manipulated. The “BoxLayout” allows placement of elements vertically, similar to the design document layout, and was determined that this was the most appropriate solution and implemented it. This solution, however, came with an issue (Box Layout — Kivy 2.0.0 documentation, 2021).

Due to the application not showing whether it was indeed accurate at the current time as the popup window had not been implemented yet, a temporary set of code was in place that would output the MSE score into the terminal, so monitoring on the success of any test drawings could be achieved. When the box layout vertically was used, the MSE error score had significantly increased, more so than previous uses with the application. Something was going drastically wrong with the image saving. Commenting out the image deletion code showed the issue, the canvas was no longer saving itself as a square image, causing major issues when then it was being resized as the user's image would be "squished" and "stretched" to form the right size. Identifying a choice of two options; the application could attempt to crop the image back to being a Square before it was then resized to the correct dimensions, or a way could be found to have the buttons present where the drawing canvas would be the correct dimensions to save as a square.

### Cropping

The method first explored was to crop the image as it was the more likely option to guarantee it looking like the design documents, and within the use of "CV2", it seemed straightforward to crop the image. In practice, although the framework had the capacity for the cropping of the image with the "CV2" library, it certainly was resistant to the use of cropping and would either produce errors due to the cropping being out of the bounds of the image, despite the boundaries being set clearly within the bounds according to the documentation of "CV2". Even if the boundaries were within the bounds that the framework would accept, it would instead crop the image incorrectly. After experimenting with a variety of different boundaries for cropping, it became clear to ensure that the rest of the application worked within the framework, instead of focusing on trying to ensure the cropping was correct, a method of fixing the issue not involving the cropping was still available (opencv-python, 2021).

Knowing that time management was key to this project, it was important to focus on getting the application to work. With more time in the future work, the cropping issue could be fixed and ensure that the UI reflected the design document, but for now ensuring the comparing was correct was the most important aspect.

### Layout Trial and Error

Experimenting with various layouts using a trial and error to attempt to find a way to have the buttons present whilst still having the canvas as a square. Initially, "BoxLayout" was dismissed as in its vertical orientation, it had caused the issue trying to be resolved. However, after exhausting various other layouts options, the horizontal orientation of "BoxLayout" was trialled. This variation gave the closest to a square image, just slightly too small on the width. After realising that the number of pixels that were being cut off from the canvas were the width of the buttons combined, the button size was adjusted until the MSE score was within the previous bounds (Box Layout — Kivy 2.0.0 documentation, 2021).

## UI Completed

This approach resulted in the following design and with some adjustments later on, it was an acceptable prototype UI.



Fig. This shows the initial prototype UI (Note, Microsoft Word effects have been used on the image to ensure clarity of the borders of the image)

With the Frontend of the Drawing Page completed, the next main point within the implementation could be coded: “Backend of the Letter Screen”.

## Backend and Frontend of the Letter Screen

After creating the prototype of the main letter screen, what was missing from the current code was the “Background Image”. As stated before, until a new screen was created it was not going to be implemented, as the user should be able to choose which template they would run the drawing with. In the design documents this was seen as a “Letter Screen” where the user would choose the letter, causing that letter to occur as the background image, as well as comparing the correct background image to the input. This would be important as it would allow the application to test a variety of data, as well as allow the user to trace the letter, the main part of the “Montessori Method” being implemented.

Implementation began by creating a new screen, which caused an issue to emerge. With one window applications, as had been taught in the Kivy tutorials, when transferring to a new screen it would be a similar process to the Python library “Tkinter”; where the window would be destroyed first before the next window was created. This did not seem like a very mobile friendly approach, as typically one of the defining features of a smooth experience on mobile applications would be seamless transitions. To create a smooth experience for the users, it was necessary to find an alternative to the current form of transitions. After researching solutions, a succinct answer was found, although it did cause some initial errors: “Screen Manager” (Screen Manager — Kivy 2.0.0 documentation, 2021).



## Screen Manager

“Screen Manager” is a widget within the Kivy framework, that exclusively takes control of the management of multiple screens within a project. Rather than causing each screen to be removed before the next appears, this widget preloads all of the screens that the current screen can access, and provides a seamless transition to the next screen, where it then repeats the process. This makes the application seem a lot smoother, and provides a fluid experience, exactly what the project required (Screen Manager — Kivy 2.0.0 documentation, 2021).

It was necessary to edit the current screen code to match the format of the “ScreenManager”, which initially caused unexpected errors within the save and clear buttons, where they would just crash the application if they were pressed. After reviewing the cause of the errors, due to the parent now being the “ScreenManager”, the pathing for each button’s commands had to be altered to reach the correct destination. Now that the issues with those had been solved and the application seemed to run successfully with only a single screen (Screen Manager — Kivy 2.0.0 documentation, 2021).

## The Letter Window

The next stage was to work on the new screen, and due to the practice and bug fixing that converting the initial screen to “ScreenManager” caused, it was simple to implement a new screen that was within the management. After doing so it was important to consider what the Letter Screen was actually doing, and how to achieve this. After consideration, it was identified that the following steps for the backend were required, that did mix with the frontend slightly:

- Each Button gives the correct Letter to the Drawing Screen.
- The correct Background Image appears.
- You could easily access all of the buttons.

After review, this would involve the front end as well, it would be more complex than the previous screen, and would instead require a hybrid form of coding, where both the backend and frontend would be developed simultaneously.

When creating all 26 buttons, labelling them A-Z so that the user could know which button went to which section, the same issue that appeared within the Drawing Screen occurred; all the buttons were in the middle. Research began into the other layouts, as it was clear that with 26 buttons a “BoxLayout” would not be the solution this time. “GridLayout”, a form of layout that allowed you to define how many columns and/or rows you would want, with the capability to align them like a table, in whatever order you specified. This did solve the issue to an extent, however, as the application was trying to fit all 26 boxes into the application window size, they were all small dimensions. A typical workaround that mobile applications, as well as desktop applications use is to allow the user to scroll through their options, allowing the boxes to be big enough to be defined and easy to read as they decide their choice. Researching into a similar workaround within Kivy, the official Kivy Discord, a real time chat program allowed you to chat with moderators about any issues you were facing using their framework. As it was unprofessional to ask for assistance writing the code, enquiring the support section regarding scrolling with your application, they pointed towards the official Kivy documentation for a widget within layouts called “ScrollView” (Box Layout — Kivy 2.0.0 documentation, 2021) (ScrollView — Kivy 2.0.0 documentation, 2021) (Discord | Your Place to Talk and Hang Out, 2021).

## ScrollView

This widget allows the developer to define the bounding box to determine where to cut off, and then allows the user to scroll within that boundary to outside the boundary, the solution that the project required. Initially implementing this widget did not lead to any noticeable difference, as the buttons were still trying to be the smallest size they could be. Defining specific button heights guaranteed them to be the right size and fixed that issue. The application now had 26 buttons that allowed the user to scroll through and press the button they wished to use. These buttons, however, had no functionality so it was now time to implement the backend of the design to allow for the buttons to successfully pass to the next screen (ScrollView — Kivy 2.0.0 documentation, 2021).

## Backend of the Buttons

The next step was to then enable the buttons to perform multiple commands. The initial research into Kivy, within the tutorials they had buttons achieve multiple commands through two methods. They either called a function that had function calls nested within the function, or they simply had “on\_press” commands listed on the same button, where it would execute all of the commands at the same time. Ensuring to not over clutter the code with nested function calls, the decision was made to use the latter method and began by implementing the code that would be the easiest to implement; getting each of the buttons to transition to the Drawing Screen. This did prove to be a success, as the “ScreenManager” code perfectly worked first time, as long as the right specification of the right ID was given.

```
Button:
    text: 'A'
    on_press: root.manager.current = 'paint'
```

Fig. This shows the Button Code to transition between screens.

After implementing this code into the other buttons, an issue arose. No research had occurred to understand how variables functioned within the Builder file of the code. The reason why this became an issue was to get a background image to appear on the Drawing Screen, the source had to be specified, and typically in Python, if you were wanting that to be a variable, you would simply define it and edit it as you wished. However, running through the code in the Builder file, it was not the same styling as Python so instead research into how variables worked within Kivy’s Builder file was required.

## Variables within Kivy’s Builder File

Researching into how variables worked within the Kivy builder file, it seemed to be easy enough when working with one screen, and only slightly more complicated when working with “ScreenManager”. It was necessary to define the variable as a certain Property within the App function, allowing it to function similar to a global variable, where you then defined it as a property, such as “StringProperty” in the case of the image path. This then allows you to access the variable within the Builder file, allowing you to edit them within the file as well, as you simply define them within a command similar to how you define python variables (Properties — Kivy 2.0.0 documentation, 2021).

## Background Image

Now that the research into the variables was completed, it became necessary to implement two of the variables, as the path for the background image would need defined, but also the search code of the right test image when it came to the comparison would need to be defined. It did occur to me that the same variable could be implemented for both, however the decision to use two ensured that no confusion could occur, to ensure that the exact correct information was being passed to the code.

Adding the Builder File commands were simple, and with an adjustment to the “CV2” code to allow for the new variable to define which image was being loaded, the “Letter Screen” was now implemented, where pressing a button would load the correct image onto the canvas. However, the issue was that the command that saved the image, now saved the test data image alongside the user data. Unsure of how to continue, the Kivy support network said that issues had occurred, as I was making the canvas itself have the image as its background, instead the solution was to have them as two separate objects but linked. When enquiring further, “RelativeLayout” was suggested. Researching into this, it allows the user to have multiple objects within a widget linked to always move to the same place, so if one is adjusted, the other is adjusted in the same manner. Reviewing this showed that this was the correct solution. It was implemented, setting the source to edit a new image as opposed to the Painter. This then solved the saving problem and the “Letter Screen” was implemented (Relative Layout — Kivy 2.0.0 documentation, 2021).



Fig. This shows the Letter Screen UI (Note, Microsoft Word effects have been used on the image to ensure clarity of the borders of the image)

## Backend and Frontend of the Title Screen

This left the “Title Screen”, which was renamed to the “Menu Screen” in the code. Similar to the approach with the “Letter Screen”, development of the backend of the code was initially prioritised before implementing the frontend of the code. However, due to the nature of the Title Screen it would again have to be a hybrid form of coding as the UI would take precedence, with the backend only being a small part of the code.

Following the design documentation, the “Title Screen” would be populated with the following:

- The Main Title of the Application
- A Draw Button that would take you to the Letter Screen
- A Settings Button
- A Button to quit the application

Reviewing the implementation, the users had no settings thus far to adjust. If a multisensory approach was to be followed, as discussed in the Background, then a mute button could be implemented for the auditory sections of the program. As this implementation would not occur during this project timeframe, and no other settings were required, this button was omitted from the implementation process.

Implementing the buttons was relatively simple, as they followed the same command structure as the Letter Screen. However, an issue arose when working with the Label. Reviewing the command to set it to scale to the right width, the code was implemented however noticed no difference. Unsure of how to proceed, the Kivy Support line was enquired into to rule out the possibility of a simple mistake. They were unsure about the cause of the error when presented it but suggested a solution to simply change the font size until the correct solution could be researched into. Implementing this did fix the issue, although it meant the application was no longer scalable as previously hoped. Given the issues with the canvas previously mentioned, a temporary solution was acceptable until more time could be spent on the project after the timeframe. Since this was the final screen, the application was technically complete in terms of the backend for the design documents for the main screens.

Something noticed when running through the application to check for bugs in the code was that there was no way to go back in the application, only being able to go forward instead. This navigational UI was important to the project so a decision was made to implement this at the end. As previously discussed there was one part of the application left until the end of implementation that still needed to be coded, the Popup Window.

## The Popup Window and Accuracy

Research began into the Popup windows, and surprisingly there was very little documentation on creating a popup within the Builder File, instead the documentation showed that users should mainly work within the Python file to create the Popup. This suited the idea for the popup code, as it was necessary to perform logic checks using the MSE score within the “save\_canvas” procedure to ensure that the correct Popup appeared.

Implementing the popup, the popup itself contained front end code to change the content of the elements within the Builder File. To ensure the content was tailored to the application, a Pass and Fail element within the file was created, allowing for populating the element with the correct phrasing, as proposed in the Approach. After implementing and setting the MSE score logic check to a value that considered “accurate” from trialling, an odd issue arose within the code. If a “C” was drawn within the “A” screen, it was considered to have less errors than the “A” drawings. This was obviously incorrect, so it became apparent something within the code was going wrong. Reviewing the saved files (Test and User), they appeared correct so either the MSE equation itself was incorrect in the “Skimage” library or the program was not reading the files correctly. Displaying the files when they were imported showed a black screen. This eventually allowed for the development of a solution to the issue.

When using “CV2”, the user specifies the type of import for the code, where it can be imported as a greyscale image (the default option), or with other methods. Unfortunately, when importing as a greyscale image, alpha pixels (also known as transparent pixels) such as the ones present in both the images would be treated as black, and this was an issue with the test data. Due to it being a black font, the entire image was considered a black square, and so was causing an issue in the comparison. Now the error was understood, a method was implemented to import via CV2 where it allows for alpha pixels to be present, so changing the import command solved this issue (opencv-python, 2021).

This caused further reflection about the MSE score, as the user was still submitting a green drawing. This could cause issues for the MSE score and cause it to be higher than it should be, meaning the accuracy would not be solely based on the user’s accuracy in their drawing as intended.

Reviewing how to change the colour of the canvas drawings before the image is saved, the canvas drawings split into two sections, the line points that turn into vector objects, and the colour objects assigned to each point. Reviewing this an editable form of this colour object needed to be created and in the code to change the colour to black, the same colour as the test data.

Reviewing the property variables again, “ListProperty”, a property that allows you to work similar to a Python list, within Kivy specific widgets like the canvas could be used to ensure this change. The code was implemented with the “on\_touch\_down” function as this would save each line colour, rather than unnecessarily appending the list with colour data every time movement was detected. It then consisted of a “for loop” for the list, changing each of the colour objects to black which then achieves the result of saving a black image of the user data (Properties — Kivy 2.0.0 documentation, 2021).

Now that the MSE score was fully working and was solely based on the accuracy of the user, it was necessary to establish the “if” statements accuracy. By experimenting with the application numerous times with the different letters, an MSE score of 1300 was decided, as it allowed the user to still get the same shape, whilst being slightly off with the transposition (E.g. being the right shape but slightly to the left). This accuracy threshold also meant that if the user drew a different letter instead of the correct letter, it would be considered a pass. If a “C” written on the “A” screen, the MSE score be a couple of thousand, certainly nowhere near the 1300 score. This made it possible to implement an “if else” statement running with the positive and negative popups, allowing for the accurate popups to appear.

## UI Work

Now that the Popup Window was set up successfully, it was time to work on some simple buttons within the “Drawing Screen” and the “Letter Screen”. Implementation began with a small button that allows the user to easily return to the previous screen by using the same code structure used within the Letter and Title Screen. This vastly improved the navigation of the application and gave the user a lot more freedom within the application, allowing them to go back if they had made a mistake regarding the letter they had chosen, helping improve the goals that the “Montessori Method” had provided.

A pure white background screen did not provide an attractive or professional look for the application, and so trial and erroring multiple colours began to create the “Controlled Environment” that the Montessori Method specifies. It concluded on shades of grey, as it evokes professionalism as well as a calm atmosphere. The colour of the line was to be a halfway point between mid and bright green, as the colour is commonly associated with positivity and good outcomes, which might improve the appeal of using the application. The use of a brighter colour also helps gain attention to what the user is doing, as they trace the letter it draws attention to the tracing, focusing the user on the task.

The Main Title used a faded blue again to evoke a calm environment. Consideration was given into using a brighter colour to help gain the users attention, however decided against it as the main stipulation in the controlled environment was having a calm form.

The final part of the UI to change was to change the font of the application. This required revisiting every element implemented and changing the “Font Family” to “LesliesHand” as it was locally saved within the files (LesliesHand Font · 1001 Fonts, 2021).

## Conclusion of Implementation

Now that the Application was successfully implemented, it was time to begin self-testing and to assess the results afterwards from the ethics approved User Testing. First though, compilation of the program had to be completed.

Now the application was ready to compile, a dual boot OS with Ubuntu as the secondary boot alongside Windows as the primary OS was installed. The application was compiled using the library that Kivy recommended: “Buildozer”. It was necessary to list every library required for the application to compile, as well as specifying the application name, icon, and the files to be included in the compiling process. After doing so the compilation of the program began, and a concerning issue occurred. The PC cooling fans began to accelerate at a rapid rate, and the entire PC began to severely overheat, to a greater extent than experienced previously. This was a thought that had been dismissed previously as there could be an increased load on the PC for compiling. However, graphical glitches began to appear on the screen and near the PC fan vents the casing became too hot to touch. Fearing irreparable damage to the computer was being caused, attempts to stop the compilation process by exiting the terminal were undertaken. However, it would not cancel, so a force shutdown was evoked to let the device cool down (Create a package for Android — Kivy 2.0.0 documentation, 2021).

As a result of the impact of the compilation process, It was decided to stop the compilation process into a mobile application, as it would still work as a desktop application to test for usability if a touchscreen laptop was used. Given more time and resources after the project timeframe, it would be possible to convert it into a mobile application then, when the UI is more akin to a mobile screen.

## Results and Evaluation

### Research Methods

During the implementation phase submission of the ethical approval forms to the Computer Science Ethical Committee (SREC) had been achieved. Originally, plans to run a short length of testing with the correct age group were expected, to allow for a brief grasp of whether the application could have its use within the School environment. This was not possible unfortunately, due to the COVID-19 restrictions at the time. Schools were struggling to keep in person teaching safe for their teachers and students, and so all the schools contacted to run the tests were reluctant in giving permission as it would be an unknown element coming into their “Bubble”.

Some schools also raised concerns, as they did not want their users to be the first users to test the application. Instead, they wanted research and groups to have already tried and given their opinion on the application first before allowing for their children to test the applications for the actual benefits.

As it was looking highly unlikely to test the efficacy of the application with the correct age group, it was necessary to change the age group targeted during the testing period. By checking the usability of the application within a more mature age group (Above 18s), the concerns the schools raised that the application was untested could be addressed and establish whether the testing user considered the application appropriate for testing with younger ages, or whether they did not think it was appropriate for the proposed age range.

This change meant resubmitting the ethical approval application with this new aim in mind. The questionnaire was adjusted, as it originally assessed whether the application was showing literacy improvement, instead of checking the usability of the application. Literacy improvement questions were still included, as the aim of the application is to show these kinds of results. This would help the consideration as to whether the application was worth a prolonged test afterwards. If the testing users reflected that the application had a negative impact on their abilities then that would require a large amount of redesigning of the application, as this outcome would be contrary to the application’s aims.

To allow for graphical data to be produced, a series of rating questions was used, where 1 was considered the most negative response and 10 was considered the most positive. This allows for the viewing each user’s data anonymously and develops into measuring the correlation within the data sets to see if the application was indeed a success. In the questionnaire, a set of Agree or Disagree statements were included to find out their opinions. By using this data, it can be collated and used to find out general opinions of the group rather than focusing on each individual user response. This allows for the extrapolation of what a larger group would consider to be the general opinion. The questionnaire was completed with an open-ended question, allowing the user to accurately represent their experience. It was decided to ask what they wanted specifically to improve in the application as it would allow for improvements in the application before running a prolonged test on the age range the application was made for.

There were a total of 15 participants in the sample. This is less than would be considered ideal however due to COVID-19, people were less willing to come try out the project in person in case of transference of the disease. This is still a substantial enough group to make suggestions and work out preliminary solutions. However, any claims cannot be brought forward as a much bigger user set would be required to use the application first. The group themselves were composed of a mix of university and non-university educated adults from the age range of 20-30, as this mix allowed for the gauging in usability of the program from the adult perspective.

### Graphical Data from the Questionnaires

To ensure anonymity, the Users positions for the graphical data was randomised for each graph, e.g. User 1 for Graph 1 may not be the same User 1 in Graph 2.

The first two questions from the questionnaire were related to each other, allowing the user to self-reflect on their handwriting skills before the application compared to how it was after using the application:

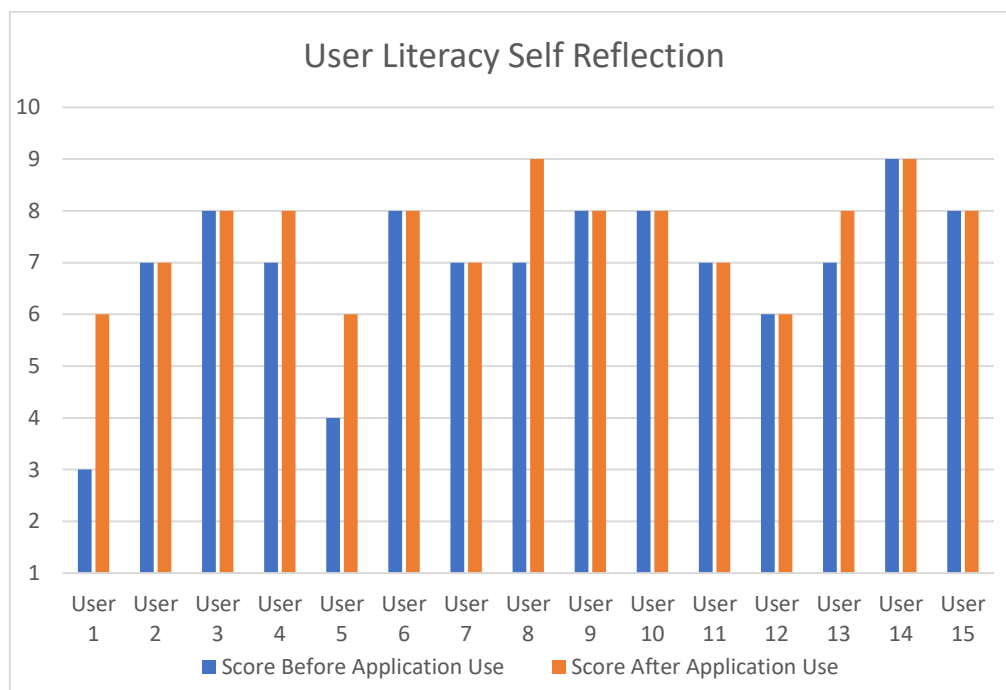


Fig. This shows how the Users rate themselves in terms of Legibility before and after the application.

Despite the application being aimed for those of a younger age, some of those who were out of the age range of the application self-reflect on showing improvement after using the application which raises two points:

- Could the applications age scope be extended to involve a more varied age range instead of just Early Years?
- This shows extreme promise for the thought of an extended test with Early Years education.

If adults have a chance to improve their literacy ability, when they were not the targeted age group, then it shows a positive base for then testing with younger years who are more susceptible to adaptation and change.



The next question was to consider the user's experience regarding how easy the application was to use, whether they came into any difficulties as it is important to ensure an easy-to-use UI when thinking about Early Years users.

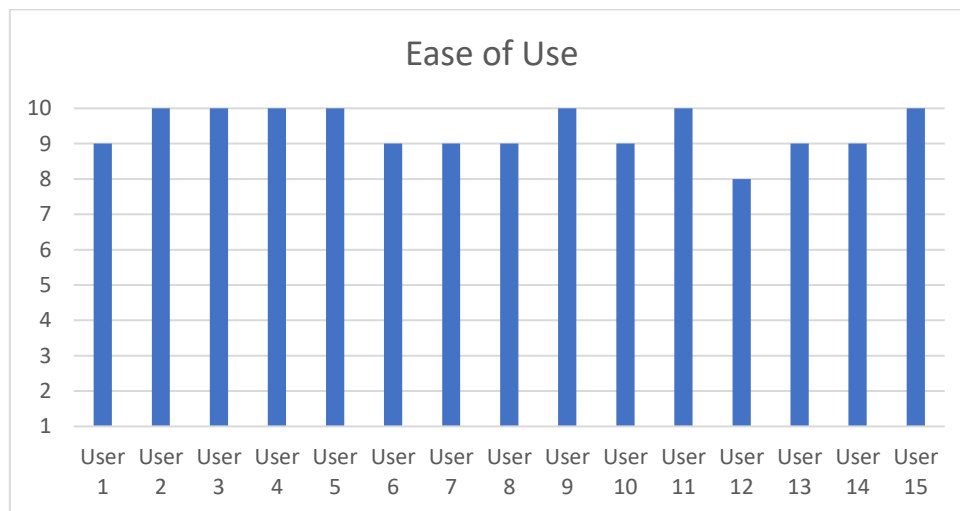


Fig. This shows the User's scores on the ease of use with the application.

From the user's scores it shows a positive result from the ease of use, with max or very high scores given from the user's testing period. This is positive on the application as a very easy to use application will be highly beneficial for Early Years.

The next question the questionnaire asked was how Inviting the application was. If the application was not very friendly for the user to use, then they would be less likely to return to the application after using it once. Given the aim to use it as a teaching tool for an extended period of time, this question contained vital data.

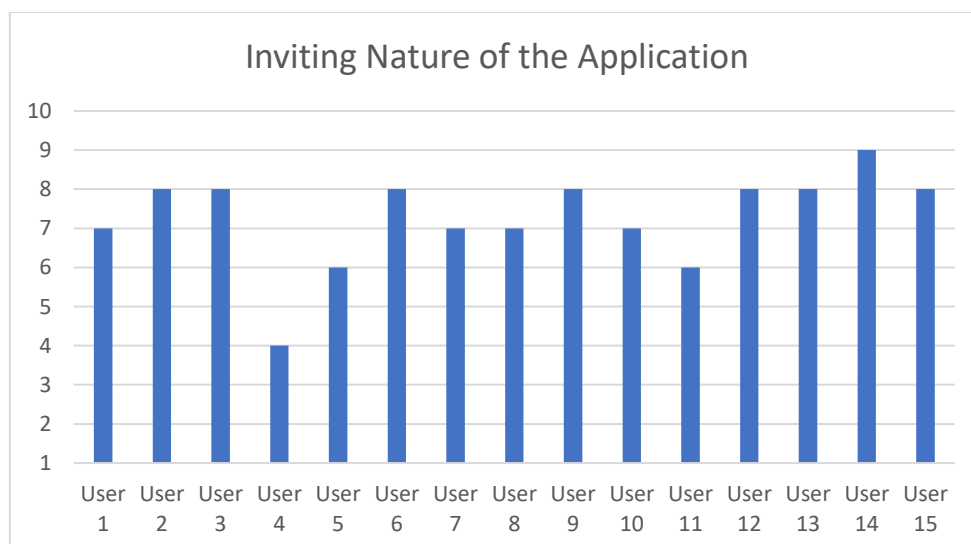


Fig. This shows the User's score based on how happy they were to use the application.

The graph outlines a mixed response from the testing users. As none of the results provide a maximum score, the comments will be reviewed at the end to understand why such varied scores were given and if possible, to work out a solution to improve these scores.

The next questions were all agree/disagree statements, so by collating the data and find the sum of agree vs disagree, a more in depth review about the user's opinions as a focus group can be obtained to make slightly more general statements.

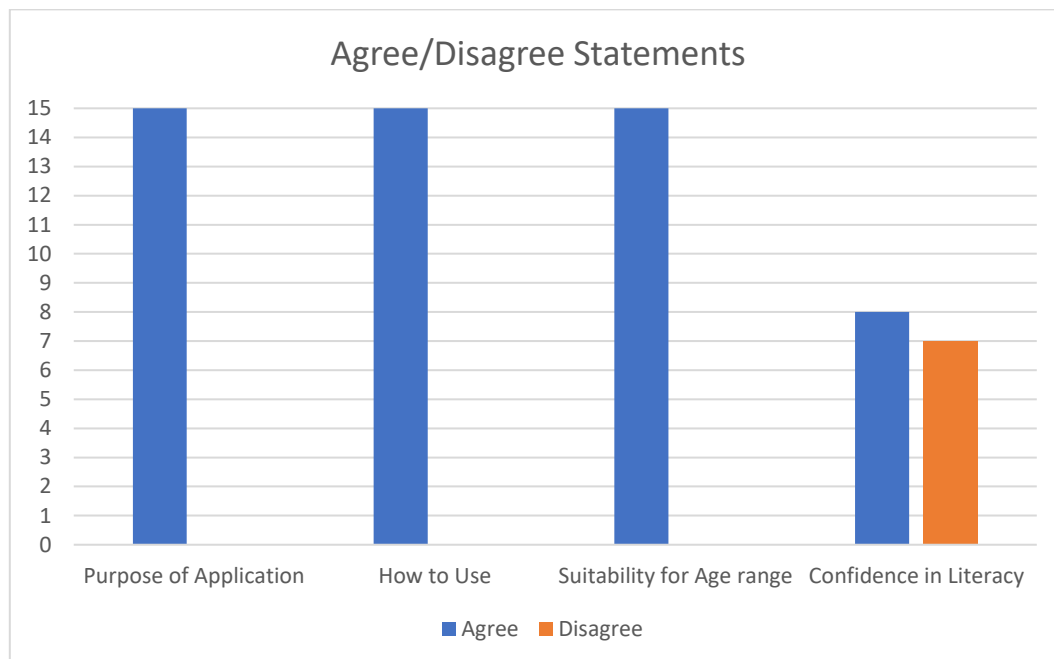


Fig. This shows the User's responses to the Agree and Disagree Statements

The first question asked whether the User understood the Purpose of the application. It shows a positive result from the users, showing that when it comes to using the application, it is quite easy to understand what you need to do and how to progress. This demonstrates a positive experience with the UI as well as the backend. As there were no negative responses, participants did not raise any issues relation to the context of this question that require to be addressed. This question is a key question from the agree/disagree statements, as an application where you do not understand the purpose of it is confusing and prevents the aim of the application from being seen.

The second question asked was whether they understood how to use the application. This directly checks the efficacy of the UI as well as providing a general opinion on the applications purpose as well. Understanding how to use the application allows the user to achieve the aim of the application and received a positive response from user, with no negative responses present.

The third question asked about the suitability of the application for "under 11s". Rather than specifying the exact age range, a general age range that the application was aimed at was proposed, as this type of application may still be useful for ages older than Early Years. This may provide a basis for potential continuation and expansion of this project to reach a larger age range. The response from the user's was again very positive, as if they believe it is suitable for that age range, it provides a good base for trying to reach a conclusion as to whether this application is beneficial for Early Years education and can help mitigate some of the apprehension that schools have expressed about the sustained testing period.

The final question was whether the user's felt more confident in their literacy abilities after using the application. Knowing this would be useful as it would a definitive response as to whether the applications scope could be extended to involve older ages. Looking at the responses, it seems to be a slightly positive response, meaning that the scope should certainly be considered in the future, but is not a definitive answer for the question. It also provides a good basis for the hypothesis as if adults are feeling more confident in their abilities, then children might do after using the application as well.

### Notes from the Questionnaires

This section considers the validity of the free-text comments from the end of the questionnaire. Due to the nature of the application. The users could have experienced issues with certain areas of the application that are required be that format for other reasons. If this is the case, then decisions must be made between keeping the application towards this objective or modifying the application to better suit the user feedback.

One common improvement suggested was an improvement on the colouring of the UI. One user stated, "Could be more visually engaging", and other users on their questionnaire have stated the same or very similar comments such as "Could look a bit nicer". The improvement is valid, and some change is necessary to make it more visually appealing especially when it comes to younger ages. However, care must be taken with regards to the visual style. Too many colours could become too distracting, and not be considered a "Controlled Environment" within the Montessori Method. Further research into what colours are more vibrant, but still considered calm is a good avenue of research to improve on the application. Something along the blue range would allow for a more colourful application that would appeal more to Early Years. According to a psychological report on how colour affects College Students, the blue colour range "encourages intellectual activity, reason, and logical thought" (Kurt et Osueke,2014 p. 4) which proves beneficial for the application as the aim is to improve their skills in literacy. The report also mentioned that it is a "soothing, calming color" (Kurt et Ouseke,2014 p. 4) which is exactly what is necessary to not distract the user in achieving their improvement (Kurt et Osueke,2014).

Another point a user brought up was "Providing the option to have different drawing colours" as it would help those with learning disabilities. This is an improvement to add, as the Montessori method is commonly used in conjunction with those with learning disabilities. A palette button on the drawing screen could be implemented, in the top right of the application to ensure difference between the drawing submission buttons and the navigation buttons. It would show "Splats" of paint in different colours when expanded for the user to decide exactly which colour they want to draw in. Due to the way the code has been implemented to turn the user's submission black, this would not prove an issue in that sense either.

A point a user added to the questionnaire was "More Visual Rewards e.g. Points or Sounds". Although points are a form of positive reinforcement, it could cause competitiveness, which could be seen as negative. In terms of the sound, as mentioned previously in the Background, the "Montessori Method" uses a multisensory form of learning so sounds should play a key part in the program so this part of the point is valid and should be added into the future work section.

## Evaluation

In conclusion, through this evaluation overall the program was a success in the testing section. There are some issues within the testing process, however the results have allowed for the gauging of the chance for success of the application with the correct age range. The sample users were not the age range I had wished, however the results given from the users provided results that should be researched further, whether from the literacy-based improvement of adults, or from the psychological point of view of their self-reflections of their literacy ability.

The questions asked were appropriate to develop an understanding of the usability within the application. The first set of questions allowed for a unique opportunity to know whether the scope of the project could be extended, as well as providing a small insight into the success of the application within the age range desired. As the feedback was positive, with some users expressing they have had self-reflected improvement; it demonstrates that the application can produce improvements in legibility and learning. The testing questions show a clear sign of a positive improvement on literary abilities and provide a positive hypothesis for younger ages as well.

## Future Work

Regarding the state of the current application, the most pressing form of future work would be to turn the desktop version of the application into a mobile platform application. When trying to convert the application to the mobile platform on a dual boot OS, it began to severely overheat the computer, and so to mitigate the risk of damage and corruption to both the hardware and the data inside the computer I had to cancel compiling and shut down the computer. The system requirements for it to be compiled would require the computer to not contain the dual boot of the Linux OS, instead ensuring Linux has full access to the system resources. This would bring the application to the point of completion within the plan of approach.

Testing did produce comments about the UI that suggest improvement is required. After discussing in the Testing section, the adaptation of the UI is important. Switching from a grey styling to a bluer colour palette will allow for a better user experience with the application, as well as still providing a calm experience throughout (Kurt,2014).

One point raised during testing relates to a consideration mentioned in the Background. Due to the time limitations within the project, the kinaesthetic form of learning was chosen from the “Montessori Method”, with no form of multisensory learning that was present for the “Sandpaper Letters” activity that the application was based on. Involving auditory stimuli such as a voice saying “A” when the “A” letter appears would provide the multisensory learning in a format more like the “Montessori Method”, allowing the application to possibly being used in conjunction with the method, as opposed to what the application current was, a teaching tool to generally improve writing (Sandpaper Letters - Refresh Your Presentations - Montessori Services, 2021).

The first point of improvement after this would be to increase the number of letters that the user can attempt to learn. The first set of data to be added would be the lower-case form of the letters already present, as making sure they have a full grasp of one alphabet before moving onto different forms would be key. This would also require some research into the importance of differentiating the Capital “I” from a lowercase “l”, many other letters can be confused with each other regarding the lower case. A clear distinction between lowercase “G”, lowercase “Q” and lowercase “P” would be required.

This would be important to do, as making sure that the application is easy to understand for all ages is important. It might also require a reworking of the MSE accuracy to ensure that the application itself can work out the differences between the shapes.

The number of letters could also be increased to include other languages, with each letter having the metadata of which language it can appear in. If the user wants to learn Russian, they could choose the language in the settings and the only letters that would appear would be the Russian characters. This could either be done by editing the metadata and searching through all the data for those specific snippets of data, or instead they could be sorted by folder, with duplicate characters being present such as “a” appearing in multiple folders as it is contained in multiple languages. This would certainly be less efficient as you would have a large amount of redundancy in the number of images, however further research would be required into implanting and reading the metadata in the images, or whether another form of recognising the letters would be necessary. Integrating multiple languages would give the application a wider scope, not only in age, as users from a vast variety of ages appreciate learning languages from step one, and applications like Duolingo lack the ability to learn how to write the characters, instead focusing on words and grammar, which has its own benefits (Duolingo - The world's best way to learn a language, 2021).

If you wish to learn a language fluently, learning how to write each character is also vastly important (particularly for character-based languages, such as Japanese) as auditory and kinaesthetic retention is different. Having language options would also be important for the scope of the project as currently the whole of the application is in English. For those who cannot understand English, it will be difficult for them to navigate the menus and use the application. Even though the UI has been tailored to be as intuitive as possible with as little complex language as possible as well, it is still going to be difficult for those who do not speak the language to fully understand what would be happening, and especially if some of the other features in the future work are implemented. Having the buttons to change language would be a useful feature to help increase the reach of the application as well as making it easier for people who are using the application as a way of learning English as a second language to navigate the menu.

In certain circumstances the labels on the buttons provided can be changed, however it would limit the creativity in the button design. Using images for the buttons instead of the native UI would help appeal more to younger ages if they were colourful and unique but would limit how I was able to affect the labelling in the buttons. Further research would be required into whether a hybrid use of both features could work. This would be a very important piece of the future work, as it allows for a greater appeal to other countries. Giving people the chance to allow themselves to learn about other languages is crucial for a greater understanding between cultures and allows applications that further impress on this teaching such as Babbel or Duolingo to create a more fluid way of digital learning. Even though it was not the original intention, the application could be developed to complement these language learning applications to create a fluid transition from a certain level of learning to the next, allowing users to progress like how school years gradually increase the difficulty of learning as to not overwhelm (Duolingo - The world's best way to learn a language, 2021) (GmbH, 2021) (Text and Badida, 2021).

Having different levels of difficulty to ensure a learning progression for the user is another aspect of potential future work. This could be achieved in one of two ways, with positives and negatives effects for each suggestion that inevitably would help the development of the user if either way were chosen.

Before addressing the potential options considered, the idea of simply requiring a lower MSE score to cause a pass to trigger was dismissed. In relation to furthering the difficulty, it is not a user satisfying method of increasing difficulty, as the user will not be able to notice any difference on the front end of the application. Changing the applications process, such as the methods I am about to discuss, will also enhance user interest as something different will be happening within the application, rather than replicating the same task leading to monotony.

The first option would be to decrease the font size, and have multiple “levels” of font size, allowing the user to attempt to make their lettering more and more accurate and closer to how a pen size would look. The pixel width would decrease, and the dimensions of the letter would decrease slightly as well, to allow for the integration into working with pens. This could prove beneficial especially in primary schools as users would get used to having to make smaller movements, like how they become used to it in the classroom. This approach comes with some drawbacks; as the size decreases, it might become too difficult for the user to accurately trace the letter with their finger or touch screen tool if they are using for example a tablet pen. This does seem like it would increase the difficulty but affecting the size of the letter could cause it to be too dextrously challenging for anyone to accurately map it with say a finger, which is the entire point of the research into the “Montessori Method”, allowing users to learn the shape of the letter with their finger as a way of learning how to write the letter themselves. Having a letter too difficult for anyone to map accurately with their finger would cause the user to be disheartened or even frustrated as it could be impossible for the MSE score to be low enough to consider the attempt a pass (Pickering, 1992).

The other form of increasing the difficulty would be to change the font style. Rather than it being the standard test data, you could instead display and compare with a new font that would be considered more complex or elaborate. This comes with several benefits, as it would allow the user not only to feel a sense of a difficulty curve, it would also allow the user to experience writing in multiple fonts, as typical human writing is an amalgamation of multiple fonts, allowing the user to start to gain this understanding and figure out which font suits them the best. This also allows the user to snap their concentration and enjoyment of the application back, as running the same test over and over can cause the monotony to become apparent and the user might stop using the application or even delete the application. The research also indicated that younger ages have some of the shortest attention span, so making sure that the application does not become too monotonous is essential to keep use of the application active (Balance, 2021).

This method however does come with some drawbacks, as the more complex fonts could experience the same issues as the previous method, when using the same large font size, the user might not be able to differentiate some of the details of the different font, and it could end up looking like a blob, so a reduction in the font width might be necessary. This raises the same issue as before, where changing the font size could cause the application to simply become too difficult to use, instead causing the user to leave due to frustration instead of boredom. The other issue is the font itself could be too complex to learn. As younger ages could be using the application or those with learning difficulties, it is vital that even at harder difficulties, it does not confuse the user or cause any previous progress to revert, so learning a more complex “G” that is a completely different shape to the previous “G” that they had been learning the entire time could cause the user’s previous knowledge of the letter to deteriorate, as well as possibly seeming like the new letter they are learning to be a letter from another language instead of the same letter. Mitigating that would be essential in making the difficulty change is allowing the user to stay with the application instead of instead finding themselves more confused after using the application.

Comparing the two methods, in the future plans for the application, changing the font itself is the way forward, as it will prevent the attention span of the user to deteriorate. However, in doing so a hybrid version of the two must be put in place, where making sure that the letter is still recognisable is key, so as the difficulty change the font, the pixel width of the letter might decrease to ensure clarity within the letter. Further research should be undertaken to ensure that the fonts chosen are still recognisable as the letters themselves. Test groups of various ages should be put in place to match the correct “pair” from various fonts of the same letter, as well as some different letters in fonts that seem similar to ensure that they are not chosen. These focus groups would allow for the correct choice in the fonts, to ensure a natural and fluid progression of knowledge within the application.

## Conclusions

Overall, the analysis of the project was more focused on testing the usability of the project instead of whether the application can provide support for teaching Early Years Education. This deviation is acceptable though as it provides a good basis for a study to be conducted afterwards around the point of providing support. This project allows for a solid base of information and does have some positive claims about the application. Due to the increase in some user's literacy ability with the use of the application, it provides some results that require future discussion.

The testing itself has proved interesting as it gives a positive recommendation from the user base to use the application with the correct age range. It also lends itself to the hypothesis that the application could be used for the age range outside of the one specified in the report, possibly allowing for anyone to use the application if they feel like they need to improve their legibility when it comes to writing on paper, something that will become more key as face-to-face interactions will be becoming more and more common.

From the testing it is apparent that the application is an overall success. Taking into consideration the comments that the users made is key, and in the future work the improvements considered to the application are discussed to ensure that the comments are fixed for future versions of the applications.

Due to the positive results given, especially to the usability, the testing of the application in its current state is a positive experience. Also, due to the data gathered there would be a positive experience from prolonged testing with the correct age range.

The Future work of the application will give the application a needed edge in the use within teaching and will allow the application to become a true success as a teaching tool if a prolonged test is carried out. It could then provide some large-scale appeal to other countries if the language future work is continued, and multiple languages are implemented.



## Reflection on Learning

### Skills

Undertaking this project, leading to the creation of this report, has enabled me to develop a number of key skills.

From the Background and Approach sections, I improved on my ability with referencing, as both sections required research into Research Papers and coding documentation, but also provided the opportunity to learn how internet articles are referenced in the Cardiff Harvard style; something I had not attempted before.

In relation to the above point, I also improved my ability in researching topics not relating to Computer Science. Due to the nature of the project, I had to look into psychology and education-based papers, which followed a very different format than I was used to. Doing so allowed me to improve my skills in looking for specific citations that I needed, and also in looking for the context for the citations to ensure I was using them in the right place for the right reason.

The Approach and Implementation allowed me to have a much better grasp on the creation of large-scale projects. Until now I had never undertaken a project involving this much time and work. This allowed me to figure out how I needed to structure the project, improving my time management as well as my critical thinking relating to managing projects.

Due to the limited timeframe, it was necessary to think critically about what exactly the user would need and decide to remove sections that I did not think were necessary. This improved my independent work skill, as well as improving my ability to take a step back when looking at these kinds of projects rather than being narrow minded about what I wanted in the project.

I learned skills in how to present a case to the ethics committee to ensure that my testing could go ahead. This is important as you need to make sure that any form of testing with other users is ethically approved to ensure that you are not taking advantage of anyone.

I improved my skills of writing user testing formatted questionnaires, ensuring that the right information would be taken from the user whilst still guaranteeing anonymity. As I had never had to phrase any questions so carefully in the past, it was a new and exciting experience to learn.

A skill I improved on as well was my pragmatism. Due to the nature of the report, a very practical approach was required to ensure that the project would be completed in both the theory side as well as the application itself.

In Implementation, I improved on my skill of prioritisation. As the project involved multiple Functional requirements, it was important to prioritise and decide which requirement should be completed first, and which parts of the application themselves should be completed, something I improved on from my Initial Plan.

## Challenges

I faced several challenges during the project. Due to COVID-19 I was unable to have as many testers as I wished to have during the testing period however I think that I overcame this issue with my phrasing of the questionnaire to ensure that the participants information was as useful as could be.

Another challenge I faced was in trying to initially get schools onboard for the testing with under 18s. This was unfortunately refused due to COVID-19 concerns, so I overcame that issue by instead testing the usability of the application with adults to ensure that I could find out whether my application was successful, even if to a lesser extent than before.

The final Main issue I faced was that the application itself was not able to easily compile into Android to allow for the easy deployment and testing. This was an issue I had to overcome to allow for testing and I think the adaptability and initiative skills I possessed showed, instead allowing it to be run on a touchscreen laptop to ensure the closest comparison with a tablet/phone for the testing is an apt adaptation.

## Work with Supervisor

As I had not discussed how many meetings I would have with my supervisor in my initial plan, I decided to have an in-person discussion at the beginning of the project with him about how often we should meet. We decided to meet when certain milestones had been made as I preferred a more independent stance on the implementation side of the coding. Due to unforeseen circumstances, I was unable to meet as often as I had hoped, however I believe that I gained as much information as I could during each meeting to make up for it.



## SCHOOL OF COMPUTER SCIENCE & INFORMATICS RESEARCH ETHICS COMMITTEE APPLICATION FOR ETHICAL REVIEW

For Office Use Only	
SREC Reference: LEAVE BLANK	Meeting/Review Date: LEAVE BLANK

SECTION 1. GENERAL INFORMATION		
Application Type:	Undergraduate	
Research Project Title:	Early Years Education	
Short Title (where applicable):	Click or tap here to enter text.	
For Staff Projects		
Name of Chief/Principal Investigator:	Click or tap here to enter text.	
Contact details (University Email):		
Other members of research team:	Click or tap here to enter text.	
For Student Projects		
Name of Student:	Alexander Hardacre	
Contact details (University Email):	C1821352@cardiff.ac.uk	
Name of Supervisor(s):	Matthew Morgan	
Contact details (University Email):	morganmjw@cardiff.ac.uk	
Other members of research team:	Click or tap here to enter text.	
SECTION 2. SCREENING QUESTIONS		
		Select Y/N
[2.1]	Is the research project categorised as 'Research' (as defined in the Cardiff University <a href="#">Policy on the Ethical Conduct of Research involving Human Participants, Human Material or Human Data</a> (Ethics Policy))?  <i>If no (i.e. the research project is a Service Evaluation or Audit), the Committee is not required to conduct a review of the proposal but may choose to do so. Please contact the Committee via <a href="mailto:comsc-ethics@cardiff.ac.uk">comsc-ethics@cardiff.ac.uk</a> to seek advice before proceeding with this application.</i>	Yes
[2.2]	Does the research project involve human participants, human material or human data (as defined in the <a href="#">Ethics Policy</a> )?  <i>If no, you are not required to submit the research proposal to this Committee. Please do not continue with this application.</i>	Yes
[2.3]	Does the research project require review by an external ethics committee (refer to Appendix 1 of the <a href="#">Ethics Policy</a> )? Please note that this includes	No

[Version 2021-1]

	<p>all research projects involving participants who lack the capacity to consent.</p> <p><i>If yes, the research project should be submitted to the relevant external ethics committee for review and does not fall within the remit of this Committee. Please contact the <a href="#">Research Governance Team</a> for further advice. <b>Please do not continue with this application.</b></i></p>	
[2.4]	<p>Has the research project been ethically reviewed by another university or research institution (for example, where the Chief/Principal Investigator for the research project is based at another institution)?</p> <p><i>If yes, please provide evidence of the review conducted (such as an outcome letter or communication) and the ethical review policy of the relevant institution or committee. <b>Please do not continue with this application.</b></i></p>	No
[2.5]	<p>Does the research project <u>only</u> involve the use of information that is publicly and lawfully available e.g. census data and population statistics published by government departments. Note: research projects involving the use of Human Data obtained from social media (or similar internet forums) do not fall within this category.</p> <p><i>If yes, please seek advice from the School Research Ethics Committee (<a href="mailto:comsec-ethics@cardiff.ac.uk">comsec-ethics@cardiff.ac.uk</a>), providing details of the information and its source. <b>The School Ethics Officer will determine whether you are required to proceed with the application.</b></i></p>	No
2.6	<p>Does the research project fall within the scope of the <a href="#">UK Policy Framework for Health and Social Care Research</a>? This Framework broadly applies to research taking place within, or involving, the health and social care systems.</p> <p><i>If yes, you will need to apply to the <a href="#">Research Governance Team</a> for Sponsorship using the Advanced Project Information Proforma (APIP) (available on the Cardiff University intranet). The Research Governance Team will advise you on the approvals that are required for the research project after it has conducted a review of the APIP and supporting documentation. <b>Please do not continue with this application until you have sought advice from the Research Governance Team.</b></i></p>	No
2.7	<p>Does the research project involve the collection or use of Human Tissue (including, but not limited to, blood, saliva and bodily waste fluids)?</p> <p><i>If yes, the research project should be submitted to the <a href="#">Human Tissue Act Compliance Team</a> (HTACT) prior to submission to an ethics committee. <b>Please do not continue with this application until you have sought advice from HTACT.</b></i></p>	No
2.8	<p>Does the research project fall within the scope of the University's <a href="#">Security-sensitive Research Policy</a>? This Policy broadly applies to research involving terrorism, extremism or radicalisation (or access to materials of such a nature).</p> <p><i>If yes, you must register the research in accordance with the Policy and comply with the IT and security arrangements contained in the Policy.</i></p>	No
2.9	<p>Has the research project received appropriate peer/scientific review? (For student research projects, review by the research project supervisor is an acceptable form of scientific review)</p>	Yes

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	<i>If no, please obtain appropriate peer/scientific review before submitting the application to this Committee.</i>	
2.10	Have you and all other Cardiff University co-applicants/ /Supervisors/Members of the research team (as listed in Section 1) completed the University's <a href="#">Research Integrity Online Training Programme</a> ?  <i>If no, please complete the training before submitting the application to this Committee.</i>	Yes
If the research project involves the use of animals, please contact the Cardiff University Biological Standards Office <a href="mailto:bsa@cardiff.ac.uk">bsa@cardiff.ac.uk</a> to seek further advice.		
<b>SECTION 3. PROJECT SUMMARY</b>		
3.1	Summarise the research project (including the purpose and its methodology) using language that would be understood by a lay person.  This project seeks to create an alternative delivery of development for children using a method called the "Montessori Method" where the user will use a smartphone application to trace letters to allow them to learn the shape of the letter	
3.2	State the research question(s).	
	Is this new method effective in allowing people to learn letters more easily?	
3.3	Estimated start date.	
	30/04/2021	
3.4	Estimated end date (usually the end of data collection).	
	21/05/2021	
3.5	Is the research project funded?	
	No	
3.5.1	<i>If yes, please name the funding body.</i>	
	Click or tap here to enter text.	
3.6	Are there any potential conflicts of interest?	
	No	
3.6.1	<i>If yes, please confirm the action you propose to take to address such conflicts.</i>  <i>Information and guidance on conflicts of interest is contained in the <a href="#">Research Integrity Online Training Programme</a> and the <a href="#">Research Integrity and Governance Code of Practice</a>.</i>	
	Click or tap here to enter text.	
<b>SECTION 4. FULL REVIEW CRITERIA</b>		
Your answers to the questions in this Section 4 will help the Committee determine whether your project requires full or proportionate review.		
		<b>Select Y/N</b>
4.1	Will the research project be performed without the participants' prior consent?	No
4.2	Does the research design include an element of deception, including covert research?	No
4.3	Will the research project involve children under the age of 18 or 'at risk' (vulnerable) adults or groups?	No

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	<i>The <a href="#">Cardiff University Safeguarding Children and Adults at Risk: Policy and Guidance</a> sets out examples of 'at risk' or 'vulnerable' adults.</i>	
4.4	Does the research project include topics which may be considered highly sensitive for participants?  <i>This includes sexual behaviour, illegal activities, political, religious or spiritual beliefs, race or ethnicity, experience of violence, abuse or exploitation, and mental health.</i>	No
4.5	Does the research project require access to records of a sensitive or confidential nature, including Special Category Data?  <i>Special Category Data is defined in data protection legislation and currently includes information about an individual's: racial or ethnic origin; political opinions; religious beliefs; trade union membership; physical or mental health; sexual life or orientation; commission of offences or alleged offences; genetic data; and biometric data.</i>	No
4.6	Is permission of a gatekeeper required for initial or continued access to participants?  <i>This includes participants in custody and care settings, or research in communities where access to research participants is not possible without the permission of another adult, such as another family member or a community leader.</i>	No
4.7	Does the research project involve intrusive or invasive procedures?  <i>This includes the administration of substances, vigorous physical exercise, procedures involving pain or more than mild discomfort to participants (including the risk of psychological distress, discomfort or anxiety to participants).</i>	No
4.8	Does the research project involve visual or audio recordings where participants may be identified?	No
4.9	Does the research project involve the collection or use of human tissue?	No
4.10	Does the research project involve more than a minimal risk of harm to the safety and wellbeing of participants and/or the Researchers?  <i>Please answer this question based on your assessment of the risks involved in this project. Further information about possible harm or potential risks to participants/researchers must be provided in Section 7 of this form.</i>	No
<b>SECTION 5. PARTICIPATION AND RECRUITMENT</b>		
5.1	How will you identify and recruit participants to the research project? Originally I was reaching out to schools to arrange for a class of children that could allow for the research to take place, however due to COVID-19, they politely refused so instead I will use a set of students from Cardiff University to check the usability of the application as well as possibly seeing if the scope of the application can be extended to adults as well	
5.2	How many participants are you aiming to recruit? <i>If applicable, please include a breakdown of participants by type and number.</i>	
<b>20</b>		
5.3	What are the inclusion and exclusion criteria for participants? There is no inclusion or exclusion criteria, I will be recruiting from as many different departments as I can to ensure the most conclusive results rather than cherry picking data	
5.4	Will the research project involve participants that are Cardiff University staff or students or clients of the University (or the place in which you may otherwise work)?	

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Yes	
5.4.1	<i>If yes to 5.4, please provide details.</i>
As mentioned above, I will recruit from various departments to ensure that it is a varied set of data. I will recruit by asking those whom I know in these departments.	
<b>SECTION 6. CONSENT PROCEDURES</b>	
6.1	Will informed consent be obtained from participants?
Yes	
6.1.1	<i>If yes to 6.1, how? Please include who will be taking consent, how consent will be recorded, when participants will be provided with information about the research project, and how long potential participants will be given to decide whether to take part.</i>
I will be using the Consent Form provided and explain the aim of the project whilst also supplying them with a Participant Information Sheet to learn about whether they wish to take part	
6.2	Will participants be offered any incentives to take part in the research project
No	
6.2.1	<i>If yes, please provide details.</i>
Click or tap here to enter text.	
6.3	If a questionnaire is to be used, will you give participants the option of omitting questions they do not wish to answer?
Yes	
6.3.1	<i>If no, please provide details of the questions and a justified reason for each</i>
Click or tap here to enter text.	
6.4	Will participants be informed that their participation is voluntary and that they may withdraw at any time and for any reason?
Yes	
<b>SECTION 7. POSSIBLE HARM TO PARTICIPANTS/RESEARCHERS</b>	
7.1	Is there is a risk of the <u>participants</u> experiencing physical, emotional or psychological harm or distress?
No	
7.1.1	<i>If yes, please provide details of how ethical issues will be handled and how any risks will be minimised. Please consider whether the research project includes topics which could be considered as highly sensitive for participants.</i>
Click or tap here to enter text.	
7.2	Is there a risk of the <u>Researcher(s)</u> experiencing physical, emotional or psychological harm or distress?
No	
7.2.1	<i>If yes, please provide details of how ethical issues will be handled and how any risks will be minimised.</i>
Click or tap here to enter text.	
<b>SECTION 8. DATA MANAGEMENT, CONFIDENTIALITY AND DATA PROTECTION</b>	
8.1	How, and by whom, will data be collected?
The only data that will be collected is a questionnaire that will be collected by myself and analysed by myself as well	
8.2	Will you be accessing or collecting Personal Data (identifiable personal information) as part of the research project?

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No	
8.2.1	<i>If yes, please confirm what data will be accessed and/or collected (including details of the information participants are asked to provide on a written consent form) and by who</i>
Click or tap here to enter text.	
8.3	<p>How long will you retain the Personal Data collected in connection with the research project?</p> <p><i>Note for Staff/PGR/PGT projects: Consent Forms should be retained for the period specified in Section 2.9 ('Research Project Conduct') of the University's Research Records Retention Schedule. If other identifiable information is being collected, researchers must ensure that this is limited to the information necessary to achieve the relevant purpose (data minimisation) and that consideration is given to whether the information can be pseudonymised/anonymised (or otherwise removed) without affecting the integrity of the research data. In most cases, it will be reasonable to keep Personal Data for the period specified in the University's Research Records Retention Schedule if retention is required to maintain the integrity of the research data and the steps above have been followed.</i></p> <p><i>Note for UG projects: the retention period specified in the University's Research Records Retention Schedule does not apply to UG projects unless the data is to be published. If there is no intention to publish, records and data should be retained until the end of the appeals process (students usually have 28 days from the date of their transcript/results to make an appeal).</i></p>
No Personal data will be collected	
8.4	What efforts will be made to anonymise the data collected (where possible)?
The Questionnaire will not contain any personal information and by asking to complete the questionnaires individually there is no chance of the participants finding out personal information about each other as well	
8.5	Are you proposing to utilise 'public task' as the lawful basis for processing Personal Data for the purposes of the research project (as recommended in the University's <a href="#">GDPR Guidance for Researchers</a> )?
Yes	
8.5.1	<i>If no, please explain why and what alternative lawful basis you propose to use.</i>
Click or tap here to enter text.	
8.6	Have you utilised/incorporated into your Participant Information Sheet the following sections from the University's template Participant Information Sheet: 'What will happen to my Personal Data' and 'What happens to the data at the end of the research project?'
Yes	
8.6.1	<i>If no, please explain why this has not been used and how you have otherwise ensured that the relevant data protection/privacy information has been provided to participants.</i>
Click or tap here to enter text.	
8.7	For how long will the collected anonymised data be retained?
<p><i>Note for Staff/PGR/PGT projects: Anonymised research data should be retained for the period specified in Section 2.9 ('Research Project Conduct') of the University's Research Records Retention Schedule.</i></p> <p><i>Note for UG projects: Unless there is an intention to publish (in which case the above retention period applies), anonymised research data should be retained until the end of the appeals process (students usually have 28 days from the date of their transcript/results to make an appeal).</i></p>	
The useful data will be retained in the project and any other data will be destroyed as soon as the project comes to an end	
8.8	Who will have access to the data?
I alone will have access to the data itself however the manipulation of the data in such forms as graphs etc will be present on my project report where my supervisor and moderator will be able to view	

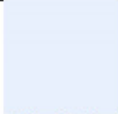

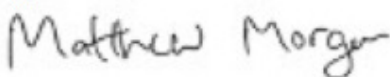
[Version 2021-1]



8.9	Will the data be shared in any way, for example through deposit in a data repository, with third parties, or a transcription service?	
No		
8.9.1	<i>If yes, provide details of all parties the data will be shared with.</i>	
Click or tap here to enter text.		
<b>SECTION 9. OTHER ETHICAL CONSIDERATIONS</b>		
Please outline any other ethical considerations raised by the research project and how you intend to address these. You are obliged to bring to the attention of the SREC any ethical issues not covered in this Ethics Review Application Proforma.		
Click or tap here to enter text.		
<b>SECTION 10. SUPPORTING DOCUMENTS</b>		
I have attached the documents, as indicated in the table below, in support of this application.		
Please note that the documents listed below <b>MUST BE</b> provided where relevant to the research project, alongside any other documents relevant to recruitment, consent and participation.		
	Yes / No	Version no.
1 Research Project Protocol/Proposal	Yes	2
2 Recruitment Adverts/Invitation Letters	No	e.g. 1
3 Participant Information Sheet	Yes	2
4 Consent Form	Yes	2
5 Data Collection Tools (e.g. questionnaires as a PDF, not a link)	Yes	1
6 Other participant communications (e.g. debrief sheets)	Yes	2
7 Evidence of Research Integrity training completion	Yes	

<b>SECTION 11. SIGNATURES AND DECLARATIONS</b>
General declaration
I confirm that:
<ul style="list-style-type: none"> <li>a. The information in this form is accurate to the best of my knowledge and belief and I take full responsibility for it.</li> <li>b. I have the necessary skills, training and or/expertise to conduct the research project as proposed.</li> <li>c. I am familiar with the University's health and safety requirements and policies and that all relevant health and safety measures have been taken into account for the research project.</li> <li>d. I am familiar with, and will comply with, the University's <a href="#">Policy on the Ethical Conduct of Research involving Human Participants, Human Material or Human Data</a> and the University's <a href="#">Research Integrity and Governance Code of Practice</a>.</li> <li>e. The relevant equality and diversity considerations have been taken into account when designing the research project.</li> <li>f. If the research project is approved, I undertake to adhere to the research project protocol, the terms of the full application as approved and any conditions set out by the Committee and any other body required to review and/or approve the research project.</li> <li>g. I will notify the Committee and all other review bodies of substantial amendments to the protocol or the terms of the approved application, and to seek a favourable opinion from the Committee before implementing the amendment.</li> </ul>
<b>FOR STAFF PROJECTS</b>
Signed:

[Version 2021-1]

	
Chief/Principal Investigator	
Print name: Click or tap here to enter text.	
Date: Click or tap to enter a date.	
<b>FOR STUDENT PROJECTS</b>	
Signed: 	Signed: 
Student	Supervisor
Print name: ALEXANDER HARDACRE	Print name: Matt Morgan
Date: 30/04/2021	Date: 23/04/2021

Please submit the completed application and supporting documents to COMSC School Research Ethics Committee ([comsc-ethics@cardiff.ac.uk](mailto:comsc-ethics@cardiff.ac.uk))

Your electronic submission should contain wet-ink or electronic signatures of all relevant parties. Please note that if any information is missing, the application may be returned to you.

## PARTICIPANT INFORMATION SHEET

### Early Years Education

You are being invited to take part in a research project. Before you decide whether or not to take part, it is important for you to understand why the research is being undertaken and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish.

Thank you for reading this.

#### 1. What is the purpose of this research project?

The purpose of the project is to develop a new method of delivering the education of spelling and to improve spelling through a mobile application. It was originally planned to be solely used for a young age bracket however I am now attempting to test the usability of the application with adults before further extending to the younger ages.

#### 2. Why have I been invited to take part?

You have been invited because you allow for a varied set of data to be used to gain a fuller understanding of the usability of the application. You also allow for the possibility of the scope of the project to be extended if it is shown that a general improvement in adults is also shown.

#### 3. Do I have to take part?

No, your participation in this research project is entirely voluntary and it is up to you to decide whether to take part. If you decide to take part, we will discuss the research project with you and ask you to sign a consent form. If you decide not to take part, you do not have to explain your reasons and it will not affect your legal rights. It should be made clear that involvement in this research project will have no effect on your education or progression through a degree course.

You are free to withdraw your consent to participate in the research project at any time, without giving a reason, even after signing the consent form.

#### 4. What will taking part involve?

The part you will play will be to use the application at least once every day for a week, trying the application and how easy it is to use and take part in. After the week I will check in with you and ask you to take part in a questionnaire about how easy the application was able to use and what you think might be improved for the future.

#### 5. Will I be paid for taking part?

No. You should understand that any data you give will be as a gift and you will not benefit financially in the future should this research project lead to the development of a new treatment/method/test/assessment.

[Version 2]

[Date 30/04/2021]

**6. What are the possible benefits of taking part?**

There will be no direct advantages or benefits to you from taking part, but your contribution will help us understand how usable the application is as well as possibly extending the scope of the application to adults as well as children.

**7. What are the possible risks of taking part?**

The risks involved may involve an increase to mental stress due to it being similar to a test, however the application risks are minimal and if you wish to discuss further feel free to contact me with the following details.

Alexander Hardacre  
98 Lisvane Street  
Cathays  
Cardiff  
CF24 4LN  
Mobile: 07528803733

**8. Will my taking part in this research project be kept confidential?**

All information collected from (or about) you during the research project will be kept confidential and any personal information you provide will be managed in accordance with data protection legislation. Please see 'What will happen to my Personal Data?' (below) for further information.

**9. What will happen to my Personal Data?**

No personal data will be used and if any is supplied by yourself or any other participants it will be immediately destroyed via the most appropriate methods (Electronic Deletion or Whiting Physical Copies) to allow for your data to be anonymised.

Cardiff University is the Data Controller and is committed to respecting and protecting your personal data in accordance with your expectations and Data Protection legislation. Further information about Data Protection, including:

- your rights
- the legal basis under which Cardiff University processes your personal data for research
- Cardiff University's Data Protection Policy
- how to contact the Cardiff University Data Protection Officer
- how to contact the Information Commissioner's Office

may be found at <https://www.cardiff.ac.uk/public-information/policies-and-procedures/data-protection>

If you are unable to access the link provided, Physical Copies will be provided.

Your consent form will be retained for the duration of the project and an additional six years afterwards and may be accessed by members of the research team and, where necessary, by members of the University's governance and audit teams or by regulatory authorities. Anonymised information will be kept for a minimum of the duration of the project



and an additional six years but may be published in support of the research project and/or retained indefinitely, where it is likely to have continuing value for research purposes.

Any anonymised data that has been collected up to the point of withdrawal may be used in the project however any data given after withdrawal will not be used and will be immediately destroyed.

**10. What happens to the data at the end of the research project?**

The data collected will be used in a singular report about the application used, no personal details will be used or disclosed, however other members from the University may view your anonymised data present on the report.

**11. What will happen to the results of the research project?**

It is our intention to publish the results of this research project in an academic report. Participants will not be identified in any report, publication or presentation. Quotes from the Questionnaire may be used within the report.

**12. What if there is a problem?**

If you wish to complain, or have grounds for concerns about any aspect of the manner in which you have been approached or treated during the course of this research, please contact Alexander Hardacre. If your complaint is not managed to your satisfaction, please contact the head of the Module: Frank Langbein at the following address [langbeinf@cardiff.ac.uk](mailto:langbeinf@cardiff.ac.uk)

If you are harmed by taking part in this research project, there are no special compensation arrangements. If you are harmed due to someone's negligence, you may have grounds for legal action, but you may have to pay for it.

**13. Who is organising and funding this research project?**

The research is organised by Alexander Hardacre from the Computer Science Department, supervised by Matthew J Morgan from the Computer Science Department in Cardiff University.

**14. Who has reviewed this research project?**

This research project has been reviewed and given a favourable opinion by the School Research Ethics Committee of Computer Science.

**15. Further information and contact details**

Should you have any questions relating to this research project, you may contact us during normal working hours:

Alexander Hardacre  
Undergraduate  
School of Computer Science and Informatics  
Cardiff University  
Queen's Building  
5 The Parade  
Cardiff  
Mobile: 07528803733

**Thank you for considering taking part in this research project. If you decide to participate, you will be given a copy of the Participant Information Sheet and a signed consent form to keep for your records.**

[Version 2]

[Date 30/04/2021]

### CONSENT FORM

Title of research project: Early Years Education

SREC reference and committee: School Research Ethics Committee of Computer Science Approved

Name of Chief/Principal Investigator: Alexander Hardacre

**Please  
initial box**

I confirm that I have read the information sheet dated 01/05/2021 version 2 for the above research project.	
I confirm that I have understood the information sheet dated 01/05/2021 version 2 for the above research project and that I have had the opportunity to ask questions and that these have been answered satisfactorily.	
I understand that my participation is voluntary, and I am free to withdraw at any time without giving a reason and without any adverse consequences (e.g. to medical care or legal rights, if relevant). I understand that if I withdraw, information about me that has already been obtained may be kept by Cardiff University.	
I understand that data collected during the research project may be looked at by individuals from Cardiff University or from regulatory authorities, where it is relevant to my taking part in the research project. I give permission for these individuals to have access to my data.	
I consent to the processing of my personal information such as Opinions based on the application and how it affected developmental growth for the purposes explained to me. I understand that such information will be held in accordance with all applicable data protection legislation and in strict confidence unless disclosure is required by law or professional obligation.	
I understand who has access to personal information that will have provided, how the data will be stored and what will happen to the data at the end of the research project.	
I understand that after the research project, anonymised data may be used to gain a greater understanding about the success of the application and could be made publicly available via a data repository and may be used for purposes not related to this research project. I understand that it will not be possible to identify me from this data that is seen and used by other researchers, for ethically approved research projects, on the understanding that confidentiality will be maintained.	

[Type here]

Appendix 4

I understand that anonymised excerpts and/or verbatim quotes from my Questionnaire may be used as part of the research publication.	
I understand how the findings and results of the research project will be written up and published.	
I agree to take part in this research project.	

\_\_\_\_\_  
Name of participant (print)

\_\_\_\_\_  
Date

\_\_\_\_\_  
Signature

\_\_\_\_\_  
Name of person taking consent  
(print)

\_\_\_\_\_  
Date

\_\_\_\_\_  
Signature

\_\_\_\_\_  
Role of person taking consent  
(print)

**THANK YOU FOR PARTICIPATING IN OUR RESEARCH**  
**YOU WILL BE GIVEN A COPY OF THIS CONSENT FORM TO KEEP**



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## Questionnaire

Please circle the answer you think best describes your response where 1 would be considered the most negative response and 10 would be considered the most positive response.

1. How easy would you say your lettering was for others to read **before** the project? Where 1 is illegible and 10 is calligraphic

1      2      3      4      5      6      7      8      9      10

2. How easy would you say your lettering was for others to read **after** the project? Where 1 is illegible and 10 is calligraphic

1      2      3      4      5      6      7      8      9      10

3. How easy was the application to use? Where 1 is very difficult and 10 is very easy

1      2      3      4      5      6      7      8      9      10

4. How inviting was the application? Where 1 means you didn't want to use the application and 10 means you were very happy to use the application

1      2      3      4      5      6      7      8      9      10

5. Please circle agree or disagree to the following statement: I understood what the purpose of the application was.

Agree

Disagree

6. Please circle agree or disagree to the following statement: I understood how to use the application.

Agree

Disagree

7. Please circle agree or disagree to the following statement: I believe the application is suitable for younger ages such as under 11 to use.

Agree

Disagree

8. Please circle agree or disagree to the following statement: I feel more confident in my literacy abilities after the project.

Agree

Disagree

9. How likely would you be to download or recommend an application of this type after using it? Where 1 means you would not recommend/download and 10 means you would be highly likely to recommend/download

1      2      3      4      5      6      7      8      9      10

10. Please circle agree or disagree to the following statement: I think the application can be improved.

Agree

Disagree

If "Agree", please In a few words describe the improvement you would make:

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Thank you for answering this Questionnaire, if you have any questions, please feel free to contact Alexander Hardacre, the Lead Researcher at the following email address:

[HardacreAT@cardiff.ac.uk](mailto:HardacreAT@cardiff.ac.uk)

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Thank you for taking part in this questionnaire.

The purpose of this survey was for me to test a new hypothesis on the learning method known as the "Montessori Method" and whether it could be adapted for use during remote learning times. From the results I will evaluate whether the method was successfully adapted and will include the results in my final project.

Your data will be held confidentially.

If you to learn anything else or wish to contact myself or my supervisor, please use the following information below:

**Researcher:**

Alexander Hardacre  
Undergraduate  
School of Computer Science and Informatics  
Cardiff University  
Queen's Building  
5 The Parade  
Cardiff  
CF24 3AA

**Supervisor:**

Matthew Morgan  
Senior Lecturer  
School of Computer Science and Informatics  
Cardiff University  
Queen's Building  
5 The Parade  
Cardiff  
CF24 3AA

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